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CHEMICAL SECTION.

Stated Meeting of March 19, 1895.

DR. W. C. DAY, President in the Chair.

[The President announced the paper for the evening, and introduced the speaker.]

COMPOSITION OF THE AMERICAN SULPHUR PETROLEUMS.

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One of the most interesting exhibits in the Department of Mines in the Columbian Exposition was the extensive collection of crude petroleums, refined products and diagrams illustrating the petroleum industry, shown by the Standard Oil Company. Of the marvelous development of our natural resources during the last thirty years, perhaps a more striking illustration could not be presented than that afforded by the petroleum exhibit.

Since the early discovery of petroleum in this country the manufacture of products obtained from it has been distinctively an American industry. In the history of its development we are struck with the great skill and originality in methods which were devised for sinking wells to great depths, and, when necessary, for removing obstacles to the free outflow of oil by exploding the wells with torpedoes, as well as in the application on a large scale of methods of fractional distillation for the separation, in a single operation, of commercial products from the crude oil. We are also impressed with the inventive genius displayed in the construction of peculiar forms of lamps, burners and heaters for household use; and in the discovery of manifold uses for the various distillates in cleansing, lubrication and medicine, and in the manufacture of soaps, candles, solvents, electric light carbons and numerous other products.

The specimens of crude oils in the Columbian Exposition showed all gradations in color between transparent or nearly colorless oils and those which were very dark and opaque, such as are used in the ordinary processes of refining. So far as it appears from the results of numerous investigations on the composition of crude petroleums from different localities, they are more nearly alike than is indicated by the inequalities in color. The main points of difference depend upon variations in the proportions of the hydrocarbons, which constitute the commercial products, such as the naphthas, gasolines, burning oils and lubricating oils.

The single method available for the examination of crude petroleums depends upon the wide variation in the boiling points of the constituent hydrocarbons, which renders possible a separation sufficiently complete for the preparation of commercial products. By this method the hydrocarbons of lower boiling points have been isolated and identified, and the composition of the more volatile portions of the crude oils has been determined with precision. Unfortunately the less volatile constituents, the hydrocarbons which distill above 250° or 300°, suffer decomposition during distillation, or, as it is termed by the refiners, they undergo "cracking." Even under diminished pressure, although a

larger quantity may be distilled, the temperature soon rises to a point at which there is considerable decomposition of the heavier distillates, and this increases with the temperature, until finally there is left in the still a mass of porous carbon representing a considerable portion of the original oil. On account of this decomposition by distillation, and the lack of any other method for the separation of the less volatile constituents of crude oils, our knowledge of this subject is still incomplete.

The discovery and subsequent development of the Ohio sulphur petroleum mark a notable epoch, even in the midst of the wonderful growth of the petroleum industry in other fields. Even with the advantage of former experience, the novel problems presented for solution in the new fields, at first, baffled the best skill of the driller and the refiner. Fortunately, from the beginning, ample opportunities were afforded for thorough scientific study of the geological formations encountered in sinking wells and the mode of occurrence of the oil, as well as of the technological features of its production. To appreciate the thorough manner in which such knowledge of the Ohio gas and oil fields has been collected and placed on record by Prof. Edward Orton, State Geologist of Ohio, it is only necessary to consult the Eighth Annual Report of the U. S. Geological Survey, and the Reports of the Ohio State Geological Survey for 1888 and 1890. These reports contain a vast amount of valuable information concerning the new gas and oil territory.

In attempting to present the merest outline of the mode of occurrence of the Ohio sulphur petroleums, I shall refer to some of the results obtained by Professor Orton in his exhaustive study of the Trenton limestone formations, with which the oil deposits are associated.

It is now well known that the distribution of petroleums within the United States is restricted to quite limited districts as compared with the total area, and that besides differences in the oils from different localities, of color, transparency and varied proportions of the individual constituents, the oils of certain fields have peculiar characteristics which

depend upon the presence of a considerable proportion of sulphur compounds. It is interesting to note that these sulphur petroleums are found only in districts quite distinct from those of the sulphur-free oils.

Public attention was first attracted to the Ohio sulphur petroleum by the discovery, in November, 1884, at Findlay, in that State, of oil and gas in considerable quantities. In that part of the Northwestern section of Ohio, known as the Black Swamp, the presence of gas and oil in creeks and pools has been known since this section of country was first inhabited; but the last decade has here witnessed a marvelous development of these natural products. The immense deposits of gas are now apparently nearly exhausted, but the copious flow of oil still continues. In the exploitation of oil in Ohio, the prospectors had all the advantage of twenty years' experience in the fields of Pennsylvania. The methods of sinking wells, as well as the manipulation of oil and the modes of treatment in refining, had been highly perfected. Markets were ready to receive the refined oils, and no time was lost in waiting for the discovery of uses for the various products. It is true that an over-stocked market has led to a large consumption of the crude oil for fuel at a quarter of its real value, but this destructive use cannot long continue.

The first oil was obtained from a well drilled at Lima, in May, 1885, and soon afterward, in the same year, oil flowed freely from a well bored at Findlay. The first production from the Hume well, in 1886, was at the rate of 250 barrels per day. In May, 1887, there were, in the Lima field alone, 445 wells producing daily 9,488 barrels; the greatest daily production of any single well was stated to be 5,000 barrels.

The discovery of a productive source of oil in the lower Silurian limestone seems to have been a great surprise to both geologists and oil-men, although the presence of oil in this limestone had previously been maintained by T. Sterry Hunt (*Am. Journ. of Science*, II, **35**, 168). As was expressed by Orton, the enormous flow of gas and oil from the dolomitic Trenton limestone constituted a new chapter in the history of petroleum production, and one of great interest, since the

Trenton beds form the most important single source of petroleum in the United States. Later developments have not only confirmed earlier observations, but have shown also that the sulphur petroleums are to be obtained in quantity, in the central part of the United States and Canada, only from the older limestones.

The Trenton limestone, one of the older formations of the continent, extends from New England to the Rocky Mountains. Occasionally outcropping, it forms excellent building stones; when burnt, valuable lime; and, by decay, fertile soils. Frequently it underlies the entire strata of large areas without appearing at the surface. In northwestern Ohio, where it forms the reservoir of the sulphur petroleums, it is usually from 1,000 to 2,000 feet below the surface, beneath a succession of shales (Utica, Hudson River and Medina) from 400 to 1,000 feet in thickness. Although the limestone seems to be permeated throughout with oil, the uppermost beds, to a depth of from 20 to 30 feet, contain the accumulated stocks, a bittern of peculiar composition occupying the space beneath.

With the history of the development of Trenton limestone oil and gas, as one of the centers of enormous production, the town of Findlay is intimately associated. The dolomitic composition of the limestone, which experience has shown to be an essential condition for gas or oil, is here present. Gas is derived from areas less than 400 feet below the sea-level, with Niagara limestone as the surface rock. The village is divided into two nearly equal portions; the east side, occupied by the Niagara limestone, is gas territory; and the west side, occupied by the Lower Heldeberg or water lime, is oil territory.

The essential features of petroleum production are source, reservoir and cover. In the Ohio fields the Trenton limestone, as the reservoir, is never wanting in oil; and the superimposed beds of impervious shales, in depths of from 500 to 1,000 feet, furnish the cover. The necessary porosity is due to the fact that the oil rock is a dolomite of highly crystalline structure. The intercrystalline spaces furnish adequate storage for large deposits of oil. The thickness of

the upper strata of the dolomitic limestone which constitutes the reservoir, is usually from five to ten feet, occasionally from fifty to 100 feet. In the Lima field, thirty feet below the surface of the Trenton limestone is recognized as the limit of the level of value for oil. The conditions, then, for the storage of oil in economic quantities depend upon a dolomitic composition of the limestone (which seems, also, to be the source as well as the reservoir), with an overlaying, impervious shale, as a cover.

Around each productive field there appears to be a sharply drawn "dead line," marking the boundaries between oil or gas and salt water, which is the propelling force of the confined oil or gas; and they occupy different levels, depending upon the height of the reservoirs. At Findlay and in the Lima fields, the highest level of the reservoirs is 300 feet below tide; the salt water level was originally 500 feet below tide at Findlay, and 400 feet below at Lima. In Indiana, the "dead line," or salt water line, in the porous reservoir, is less than 100 feet below tide. This area of 30,000 square miles is a plain over nearly its entire extent, with the Niagara limestone as the surface rock where gas is found, and the Lower Helderberg the surface rock, where oil is abundant. In the absence of outcropping oil rock, these surface indications are important guides for the location of new wells. The location and limits of the salt water line were soon learned, and, with minor exceptions, 500 feet was accepted as the limit below which it is not profitable to drill.

In 1863, Dr. T. Sterry Hunt (*Amer. Jour. of Science*, II, **35**, 170) explained that the petroleum supply of Western Ontario was derived from a broad, low anticlinal; and he maintained that the anticlinal structure is necessary in connection with hydrostatic pressure to the production of a large supply of oil. This theory has been fully confirmed in Ohio, where the flat, low-lying terraces, having a very slight elevation above the surrounding country, afford sufficient storage for immense quantities of oil. For the most part, the Ohio terraces are nearly level, with slopes of less than 1°; in general, the range in elevation throughout 100 square miles does not exceed 100 feet.

In extent, the Lima field is from eight to ten miles in length, and from two to three miles in breadth. The elevation of the surface above the sea level is from 800 to 900 feet; the gas rock is nearly level and about 380 feet below tide.

The Findlay field is also a low, nearly horizontal terrace of Trenton limestone, about 1,250 feet deep and two miles wide in a north and south line, by less than five miles east and west. The plains of Northern Ohio form the cover of the most prolific oil field yet found on the American continent, and second only to the great Russian field in the Caucasus (Orton, Geol. Report', and yet the deposits of oil seem to be singularly restricted in area. Outside of the Ohio and Indiana horizon, drillings 1,000 miles distant have yielded neither gas nor oil, the Trenton limestone failing to be a source beyond this limited district.

The two conditions under which Trenton limestone has yielded oil or gas are porosity and relief. The highly crystalline dolomitic composition supplies porosity, and a slight warping of the strata furnishes a reservoir in which are stored the enormous quantities of oil and gas above the salt water. Dr. Hunt described this brine as derived from the saline deposits evaporated from the ancient seas. In an examination of the brine from Trenton limestone, Lord found that it consisted chiefly of the chlorides of sodium, calcium and magnesium. In numerous examinations made in this laboratory, of salt brine collected in wells drilled for gas, there have been found bromine, iodine and lithium.

Oil is very widely distributed in the Ohio limestone. Hunt estimated the Chicago oil dolomite to be one foot thick and to contain one-tenth of one per cent. of oil. The same quantity in the Ohio rock would furnish, in every square mile of strata 500 feet thick, more than 2,500,000 barrels of oil; in a depth of 1,500 feet, 75,000,000 barrels. As determined by Lord, the amount of oil in the shales is equivalent to one-fifth of one per cent. Calculating this proportion for each square mile, to a depth of 1,000 feet, the total amount would exceed 10,000,000 barrels (Orton). The amount of oil in the Ohio rocks, therefore, is large even beyond computation,

but it has no economic value except when accumulated under pressure in reservoirs.

Throughout the oil and gas regions in Ohio and Indiana, the salt water in the Trenton limestone rises under free flow to about 600 feet above tide. The pressure is attributed to salt water collected in artesian reservoirs in the porous limestone which rises to the surface in Michigan and Illinois. It is there open to the admission of surface waters, which exert a pressure proportionate to the head, and the oil and gas collecting by gravitation in the limestone reservoirs are subjected to a corresponding pressure.

Professor Orton suggests as a probable explanation of the formation of the oil rock, that the original pure limestone, formed from crinoids, was replaced in part by magnesic carbonate derived from sea water, and as the new crystals did not completely occupy the spaces left vacant by the removal of the crystals of calcic carbonate, the infiltration of liquids became possible. The limited series of collected facts and observations is not sufficient to explain the precise character of the metamorphic changes.

In Canada, petroleum seems to be distributed in limited quantities over an extensive area, but not in sufficient accumulations to have economic value. The presence of oil on the waters of creeks and pools first attracted attention at Oil Springs in 1860–61. Dr. Winchell estimated that not less than 5,000,000 barrels of oil flowed off on the waters of Black Creek during the spring and summer of 1861. The sole supply of oil is derived from the territory at Petrolia and at Oil Springs, the former with an area of eight square miles, and the second two square miles in extent. The geological formations are here even less complicated than in the Ohio oil fields, since the oil deposits are much nearer the surface. The same conditions of structure are found, viz.: source, reservoir and cover, that have been established in Ohio. Instead of the Trenton limestone, the prolific source in the neighboring territory, the Corniferous limestone contains the oil deposits, with a corresponding shale above, which serves as an impervious cover. The following section of a well at Oil Springs (H. P. Brummel, Can. Geol. Rep., 1888-

1889) explains the composition of the rock strata at this point.

	Feet.
Surface	60
Upper limestone	35
Shale (upper soapstone)	101
Middle limestone	27
Shale (lower soapstone)	17
Lower limestone	130
	370

The wells are supposed to be sunk sixty feet into the Corniferous limestone.

Section near the Imperial refinery, Petrolia—

	Feet.	
Surface	104	Hamilton
Upper limestone	40	
Shale (upper soapstone)	130	
Middle limestone	15	
Shale (lower soapstone)	43	
Hard white limestone	68	
Soft limestone	40	Corniferous
Gray limestone	25	

The geology of the Canadian oil deposits was first investigated by the late Dr. T. Sterry Hunt, and on his conclusions was based the first and most probable explanation of the origin and storage of limestone oils (*Am. Journ. of Science*, II, **35**, 168). He asserted that these oils owe their formation to the decomposition of animal remains in the midst of a marine calcareous deposit. The cavities of the shells and corals afforded sufficient space for the storage of the oil as it was formed. It is here clearly stated that the limestone is both source and reservoir. Whatever may have been the conditions of formation of petroleum and its deposition in other regions, subsequent developments in the Ohio fields have fully confirmed that portion, at least, of Hunt's hypothesis, which makes the older limestone formations the reservoir of the petroleums in question.

The Canadian oil deposits are much nearer the surface than those in Ohio. As shown above, the depth of wells at Petrolia was formerly less than 400 feet, and at Oil Springs

less than 200 feet. In the township of Enniskillen the depth and flow of several early wells were as follows:

	Barrels Daily.
At a depth of 155 feet	2,000
" " 158 "	3,000
" " 167 "	6,000
" " 188 "	6,000
" " 237 "	7,500

It is therefore evident that the flow of oil from some of the Canadian wells has been very large. In 1889 there were thirteen refineries, nine at Petrolia and four at Oil Springs.

The supply of oil came from 3,500 wells, of which 2,500 were at Petrolia. The monthly production at Oil Springs amounted to 20,000 barrels, and the annual consumption, as nearly as could be estimated, was 704,690 barrels. At present the total number of wells is 8,000, of which about 6,000 are in operation at Petrolia. The annual production, as estimated by one of the best-informed oil men at Petrolia, is 800,000 barrels annually, including the monthly output at Oil Springs, which is 17,000 barrels. The average depth of wells at Petrolia is now 465 feet, and at Oil Springs, 380 feet. From the large number of wells, it is evident that the average daily production of individual wells is small. When first drilled, a well may yield a barrel or more daily, but the flow finally falls to one-half or one-third of a barrel. The small daily yield, however, is offset by the long life of the wells. Most of the wells flow steadily during long periods, some as long as thirty years.

A peculiar method of storage has here been adopted, depending upon the impervious quality of the Erie clay. It consists of a tank, in the earth, 30 feet in diameter and from 50 to 60 feet deep, having a wooden lining to a depth of 30 feet. The surface of the tank below the wooden casing is of clay, and the capacity of the tank is from 5,000 to 10,000 barrels. The total capacity of the tanks in both fields is 1,000,000 barrels. Oil is collected from the individual wells in wagon tanks and brought to receiving tanks, from which it is pumped to the central stations near the refineries.

Canadian oil is refined in the ordinary manner. Much gas is evolved, which, as usual, is serviceable in heating the retorts. In the crude still, gasoline and burning oil are run off to 37° Beaumé, and the residue is then transferred to the tar still, from which heavy oils are distilled to 30°.5 Beaumé, and the residue coked. The last distillate is again distilled and the residue coked as before. In refining, much depends upon the skill of the operator. With careful treatment and the use of an alkaline solution of plumbic oxide, a burning oil of excellent quality is prepared. From Petrolia crude two per cent. of naphtha is obtained, and from Oil Springs, seven per cent. The yield of burning oil from both sources is forty-three per cent. The quantity of tar is thirty per cent. of the crude oil, from which the yield of heavy oils is twenty per cent., with a residue of coke equivalent to ten per cent.

The anticlinal system is well marked in the Canadian fields, and is similar to that of the oil-bearing limestone formation in Ohio. The anticlinals are low terraces, and the oil collects on the slopes toward the summit, where it is held under pressure by the salt water. The variations in the oil-bearing strata have been carefully studied by Messrs. M. G. Woodward and F. J. Carman, from whom I obtained valuable information concerning this and other features of oil production in the Canadian fields.

At present the main producing field at Petrolia is five miles in length and two miles in maximum width, on an anticlinal, which takes the direction of W.N.W. by E.S.E. Much prospecting has been carried on outside of the producing fields, and has shown that the Corniferous limestone is reached at Petrolia, at 335 feet. Sixteen miles distant from Petrolia, at Sarnia, in a west-northwesterly direction, it descends to a depth of 503 feet. East of Petrolia the stratum again dips to 390 feet, and again rises, and at this point many attempts, some partially successful, have been made to discover another deposit similar to that at Petrolia. Still farther distant, in a southeasterly direction from Georgian Bay, the Corniferous limestone outcrops; and still farther away, the Trenton limestone appears at the surface.

The latter formation may be reached beneath the Petrolia anticlinal at a depth of 2,000 feet or more, but it is not, as in Ohio, an important reservoir of oil. Independently of the main producing fields in this section, much oil has been taken from "pockets;" indeed, the great producing wells seem to have derived their supply from these sources. Two years ago, while surveying a section just outside the line of productive territory, and partly surrounded in a semicircle by flowing wells, an oil man suggested the possibility that a pocket might be found in this space. Upon sinking a well, oil was found in quantity, and it proved to flow, as predicted, from a pocket which has since yielded a large supply.

The oil territory at Oil Springs is situated on an anticlinal parallel to that which supplies oil at Petrolia, and ten miles distant. As already explained, the oil rock is nearer the surface, and in addition to the great wells which undoubtedly came from pockets, until recent years the daily flow was ten or fifteen barrels. At present it does not much exceed the flow at Petrolia previously mentioned. It has been thought very probable that the anticlinal which contains the Oil Springs deposit encloses other deposits, and, consequently, much prospecting has been done along the direction of this anticlinal, especially in the township of Euphemia, where oil has been found in limited amounts, at a distance of twenty miles from Oil Springs.

In studying the geology of the sulphur petroleums, striking differences are observed in comparing the geological formations in different localities. While it seems very probable that the deposits of oil in the Ohio and Canadian territory have been formed in the limestones by the decomposition of animal remains, in other localities sulphur petroleums are found in rock formations essentially different from the limestone deposits. In the volume of the Geological Survey of Kentucky, published in 1891, Orton gives an account of the geological formations connected with the oil deposits in that region. While similar conditions of source, reservoir and cover are there found with porosity and the anticlinal structure, a black shale constitutes the rock in which the oil is stored, placing the oil in the Devo-

nian formation instead of in the lower Silurian, which is the horizon of the Ohio sulphur oil. It is explained that the essential difference in the rock formations in which oil is stored is only in degree, as is shown by the wide distribution in Ohio, where there is scarcely a geological formation that does not contain oil. The different shales contain it in variable quantities, but the necessary conditions of accumulation (impenetrable cover, etc.) for economic production are wanting.

In reviewing the distinctive properties of the limestone oils, as compared with Pennsylvania oil, Orton states in this report that they are dark in color, heavy, with a high specific gravity, and a rank odor from the sulphur compounds they contain. In these respects it is found that the oils of Canada, Kentucky and Tennessee, the new field in Northwestern Ohio, and the oil of the Utica shale and Hudson River group, in the latter State, are similar. In accounting for the storage in the shales, their natural agency is based upon their impervious quality, which prevented rapid decomposition of vegetable matter, with the aid also of the affinity of the clay for oil.

A marked peculiarity in the geological formation containing deposits of sulphur petroleum is found in California. These deposits have been carefully studied by Professor S. F. Peckham (Geol. Surv. of Cal., Vol. 2, Appendix). The source of the California bitumen is invariably a bluish slate or shale, more or less compact, with a variable mixture of fine quartz sand. There are occasionally outcroppings of bitumen, but the conditions of reservoir and cover, which have been found essential in oil deposits where oil is stored under pressure, here seem to be largely or entirely wanting, with the result that the oil deposits exert a low pressure if any. The oils obtained from these deposits are quite different in their properties from the Pennsylvania oils, and, in fact, from any other American oils that are the source of commercial products. Their specific gravity is very high (0·875–1·653), and very small quantities distill within the limits of burning oil distillates; in fact, without resorting to cracking, probably very small quantities of illuminating

oils can be prepared from this petroleum. The percentage of sulphur is higher than that of the other sulphur petroleums, as well as the percentage of nitrogen, which varies between 0·56 and 1·12. As is pointed out in the description of this petroleum, there is strong evidence in favor of its formation from animal remains. Certain constituents of the crude oil are so unstable that when exposed to the air for some time the oil becomes impregnated with maggots.

A description of the occurrence of petroleum in any particular district can hardly be considered complete without some reference to the enormous deposits of oil at Baku, on the shore of the Caspian Sea. Although the oils from this region contain no considerable quantity of sulphur, in some respects and with reference to certain other constituents, the sulphur oils may be found to resemble the Russian product. As in other oil regions the sections furnishing oil at Baku are quite limited in extent. The great district of Balakhani, with an area of from four to five square miles, is about eight miles north of Baku on the coast; and two or three miles south of Baku on the seashore is another very small district, Bibi-Eibat. Statistical or other reliable information concerning the Russian oil fields is meagre, and the points here presented are taken from the report for 1886 of the United States Consul, J. C. Chambers, at Batoum. According to this report the depth of the wells varies between 175 and 1,030 feet.

The deepest well at Bibi-Eibat, 700 feet deep, produced from 30,000 to 40,000 barrels daily during fifteen days, after which it ceased to flow. Very little information is accessible concerning the geology of the Baku district beyond the fact that the oil is derived from the Tertiary formation.

FORMATION OF PETROLEUM.

The formation of petroleum has received much attention from both the chemical and the geological point of view, and the prevailing theories have been ably presented and discussed by Professor Orton in the reports mentioned above. Until the discovery of great quantities of oil in the Trenton limestone, the geologists, in this country at least,

attributed the formation of petroleum exclusively to the decomposition of vegetation. The early suggestions of Hunt that the formation should be referred to animal remains in the limestones of the primitive rocks, attracted little attention until they received support from recent discoveries. Abroad, the prevailing belief seems to have been that the formation of all petroleums should be referred to the decomposition of animal remains. Credence is still given by some writers to the theory of Mendelejeff that all petroleums have been, and are still, formed by the action of water on iron or iron carbides, highly heated within the earth; but for lack of proof and the serious objections based upon observed facts, urged by geologists, this explanation is not generally accepted. At present the data collected seem to be insufficient to establish any particular method of formation. Even if the theory of animal origin be accepted for the limestone oils, it cannot be asserted that vegetable remains may not have been in part instrumental.

In 1865 Warren and Storer (*Mem. Amer. Acad., N. S.*, **9**, 177) subjected a lime soap prepared from menhaden oil to destructive distillation, and obtained a hydrocarbon, naphtha, from which they separated several series of hydrocarbons identical with those which Warren (*Mem. Amer. Acad., N. S.*, **9**, 156) had previously identified in Pennsylvania petroleum. More recently, Engler (*Ber. der deutsch. chem. Gesellsch.*, **21**, 1816) submitted the American menhaden oil to destructive distillation under high pressure, and, in the product distilled, was able to identify the constituents ordinarily separated from natural petroleum, including naphtha, the burning oil hydrocarbons, and paraffine. Engler therefore concludes that all petroleum has been derived from the decomposition of similar organic remains under the same conditions. Probably no better summary of the present state of the theories concerning the origin of petroleum can be given than that suggested by Orton (*Geological Survey of Ohio*, Vol. VI., p. 82).

(1) "Petroleum is derived from organic matter.

(2) "Petroleum of the Pennsylvania type is derived from

the organic matter of bituminous shales, and is probably of vegetable origin.

(3) "Petroleum of the Canada type is derived from limestone and is probably of animal origin.

(4) "Petroleum has been produced at normal rock temperatures (in American fields), and is not a product of destructive distillation of bituminous shales.

(5) "The stock of petroleum in the rock is already practically complete."

CHEMICAL COMPOSITION OF PETROLEUM.

Although various attempts had previously been made to separate the constituents of petroleum, the first systematic examination was undertaken in 1862 by Pelouze and Cahours (*Compt. Rend.* **54**, 1241; **56**, 505; **57**, 62), who identified the presence of the series of hydrocarbons C_nH_{2n+2}, beginning with butane, boiling at 0°. From their results, Pelouze and Cahours assumed that the heavier oils and paraffine have the same composition as the hydrocarbons of lower boiling points, and, as a generic term for the series, Watt suggested the name paraffine hydrocarbons, by which these constituents of petroleum have since been known in chemical literature. Members of the same series were observed by Schorlemmer (*Journ. Chem. Soc.*, 1862, 419), in a product distilled from cannel coal; and in a distillation of American petroleum, Schorlemmer obtained other members of the series that had been overlooked by Pelouze and Cahours. C. M. Warren (*Mem. Amer. Acad., N. S.*, **9**, 156; *Proc. Amer. Acad.* **27**, 56) undertook a more thorough investigation of Pennsylvania petroleum, conducting the separations in a fractional condenser which he had devised especially for such distillations. In a long course of distillations, Warren separated two series of hydrocarbons, beginning with butane, with an homologous difference in boiling points for CH_2 of 30°, and with a difference in boiling points between the members of one series and the isomeric members of the other, of a little less than 8°. One of the series, C_nH_{2n+2}, identified by Warren, terminates at 127°·8, the other at 150°. The fractions of higher boiling

points were found to contain members of the series C_nH_{2n}. The results of Warren indicated, in the distillates above 150°, the absence of members of the series C_nH_{2n+2}, notwithstanding the assertions of Pelouze and Cahours, that distillates from these portions of petroleum have the composition homologous with marsh gas. In the earlier examinations of American petroleum by Pelouze and Cahours and by Schorlemmer, it is somewhat uncertain to what extent Pennsylvania crude oil was employed, and to what extent Canadian oil, since in allusions to the crude product American petroleum is mentioned, with occasional reference to Pennsylvania or to Canada as the particular source.

The presence of aromatic hydrocarbons in American petroleum was first established in 1856, by Schorlemmer, who identified benzol and toluol in a distillate collected below 150° from Canadian petroleum, by treating this portion of the oil with nitric acid, reducing with tin and hydrochloric acid and distilling with sodic hydrate. The oil distilled had the odor of aniline and gave the rosaniline reaction with bleaching powder. The distillate between 150° and 170° gave a mixture of liquid and solid nitro-products, and the solid portion was recognized as trinitrocumol. Benzol and its homologues have since been found in Pennsylvania petroleum by several chemists. Petrocene was investigated by Sadtler (*Amer. Chem. Journ.*, **1**, 30). From American kerosene, in a portion distilling at 170°–190°, Engler (*Ber. der deutsch. chem. Gesellsch.*, **18**, 2234) separated pseudocumol and mesitylene, by the formation of nitro-compounds, and he estimated that the quantity present in crude Pennsylvania oil is equivalent to 0·2 per cent. Engler also identified these hydrocarbons in German, Galician, Italian and Russian petroleum; in the latter, to the extent of 0.1 per cent. After ascertaining in the petroleum of the Central Caucasus the presence of hexahydro-derivatives of the aromatic series, Beilstein and Kurbatoff (*Ber. der deutsch. chem. Gesellsch.*, **18**, 2028) examined American ligroin for the same hydrocarbons, but succeeded in identifying only hexahydroisoxylol. No at-

tempts were made to ascertain the presence of the higher homologues.

The petroleum from various localities in the Caucasus has been quite thoroughly investigated by Russian chemists, and it has been found to differ in its composition very essentially from Pennsylvania oil. It is held by Mendelejeff, Engler and others, that none of the petroleums, so far as they have been examined, differ essentially with respect to their components; but that the observed variation in the qualities of different oils depends rather upon a variation in proportions. This difference in proportions, however, is so marked, that in certain oils some of the constituents constitute nearly the whole body of the oil, with others present only in minute quantities, in comparison with other oils, in which the former constituents are almost entirely absent, the great body of the oil consisting of substances nearly wanting in the first. The thorough investigations on the composition of the Caucasus petroleum by Markownikoff and Ogloblin (*Ann. Chim. Phys.*, VI, **2**, 372) proved the presence, in oil from Baku, of benzol, toluol, iso-xylol, pseudocumol, mesitylene, iso-durol, durol and higher hydrocarbons with their structure not yet determined, $C_{11}H_{14}$, $C_{11}H_{12}$, $C_{12}H_{14}$, and $C_{13}H_{14}$, with indications of the homologues of styrol and phenylacetylene. The results of Beilstein and Kurbatoff indicate the presence in the petroleum from the Central Caucasus, of members of the series, C_nH_{2n+2}, with benzol and toluol, and that the oil from the coast of the Caspian Sea consists mainly of the homologues of hexahydrobenzol. In the oil from the Balechene plain on the Apscheron peninsula, Markownikoff and Ogloblin found large quantities of the aromatic hydrocarbons; but in oil from the Central Caucasus they found naphtenes to the extent of eighty per cent. of the crude oil, and the aromatic hydrocarbons to the extent of ten per cent. At first, Markownikoff looked upon the naphtenes as isomeric with the hexahydro-compounds; but later Markownikoff and Spady (*Ber.*, **20**, 1850) appeared to accept the identity of octonaphtene and hexahydroisoxylol. Markownikoff and Ogloblin proved also the presence of hexahydromesitylene,

besides other oils with the composition C_9H_{18} and the members intermediate to $C_{15}H_{30}$.

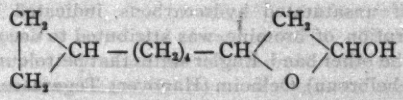
Benzol and its homologues were identified in Hanover petroleum by Bussenius and Einstuck (*Ann. Chem. und Pharm.*, **113**, 167), and by Ulsmann (*Ann. Chem. und Pharm.*, **114**, 279). In petroleum, from Boryslaw, in Galicia, Lachowicz (*Ann. Chem. Pharm.*, **220**, 187) found benzol, toluol, isoxylol and mesitylene; but of the hexahydro series, only hexahydroisoxylol. Pawlewski (*Ber. der deutsch. chem. Gesellsch.*, **18**, 1915) found in Galician petroleum two per cent. of aromatic hydrocarbons, chiefly benzol and *p*-xylol, the latter recognized for the first time in any petroleum. Naphthalene, anthracene, their homologues and other allied hydrocarbons, have been reported from various sources.

Concerning the presence of unsaturated hydrocarbons in crude petroleum, there seems to be a wide difference of opinion. Some investigators have doubted the existence in crude oil of these bodies, and where they have been found in distillates it has been assumed that they have resulted from decomposition by distillation. In the lower fractions of Galician oil, Lachowicz obtained no reaction with bromine, even after long standing. Above 200°, the presence of unsaturated hydrocarbons, indicated by the ready absorption of bromine, was attributed to decomposition. On the other hand, Engler states that petroleum from Elsass (Pechelbronn), Oelheim (Hanover), Tegernsee, Pennsylvania, Galicia and Baku, contains members of the series, C_nH_{2n+2}, and the series C_nH_{2n}, both unsaturated hydrocarbons and naphtenes. Markownikoff and Ogloblin (*Ber.*, **16**, 1873) allude to the presence of unsaturated aromatic hydrocarbons in the oil from Baku.

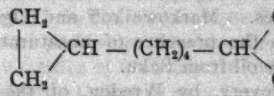
Before the discovery, by Wreden, of the hexahydroaromatic compounds, Warren separated from Pennsylvania petroleum a series of hydrocarbons C_nH_{2n}, which were probably of the same series. It now seems probable that the constituents of Pennsylvania petroleum above 150°, assigned by Pelouze and Cahours to the series C_nH_{2n+2}, really belong to another series.

It has long been known that analyses of crude petroleum

have shown less than 100 per cent. of carbon and hydrogen, and the deficiency has been attributed to the presence of oxygen. The first attempt to separate oxygen compounds from crude petroleum was made in 1874, by Hell and Medinger (*Ber.*, **7**, 1216), who agitated crude petroleum with a solution of sodic hydrate and then added sulphuric acid in excess to the alkaline solution. The oil which separated was distilled and converted into a methyl ether; by saponification of this ether an acid was obtained, to which was assigned the provisional formula $C_{11}H_{20}$. Aschan (*Ber.*, **23**, 867; **24**, 1864; **25**, 3661) obtained a mixture of acids by the addition of sulphuric acid to the sodic hydrate solution used in the refining of Baku oil; one acid, $C_8H_{14}O_2$, was obtained, that distilled at 237–239°; and another, $C_9H_{16}O_2$, that distilled at 251–253°. Aschan called the first acid octonaphtenecarboxylic acid; by distillation with hydriodic acid it was converted into hexahydroxylol. By similar methods Zaloziecki (*Ber.*, **24**, 796, 1808) separated oxygen compounds from petroleum, which were readily oxidized to acids when exposed to the air. For one of these bodies, assuming it to be a lacto-alcohol, Zaloziecki suggested the formula



and to the hydrocarbon obtained by distillation, he gave the formula



Engler asserts that the acids separated by this method are oxidation products of other constituents of the crude oil. Markownikoff and Ogloblin stated that the distillate 75°–85°, from Caucasus oil, contained 0·76 per cent. of oxygen compounds, and the fraction 220°–230°, 5·21 per cent. The oxygen compounds are in part acid, in part neutral, and in part phenol. The acids $C_{10}H_9COOH$ and $C_{11}H_{11}COOH$ were

obtained as colorless oils (*Ber.*, **16**, 1878). Markownikoff and Ogloblin regarded these substances as naphtenecarboxylic acids. Sainte-Claire Deville (*Comptes Rendus*, **66**, 442; **68**, 485; **69**, 1007), showed that the percentage of oxygen in oils from different localities varies between 2·1 per cent. in the Canadian petroleums, and 5·6 per cent. in the oil from Zante.

Most of the petroleums contain nitrogen, usually in minute quantities. Beilby (*Jour. Soc. Chem. Ind.*, **10**, 120) found 0·08 per cent. of nitrogen in the residuum from Pennsylvania oil, and 0·37 per cent. in the coke, which corresponds to 0·008 per cent. of the crude oil; crude Russian oil gave ·05 per cent. of nitrogen. In examining oils from different localities for nitrogen, Peckham (Geol. Survey of Cal., vol. ii, Appendix) found in petroleum from West Virginia, 0·54 per cent.; in Mecca oil, 0·23 per cent.; and in California oil, from 0·56 to 1·1 per cent. In Egyptian oil, Kast and Kunkler (*Chem. Centralbl.*, 1890, 932) found 0·3 per cent. of nitrogen, 1·21 per cent. of sulphur and 0·2 per cent. of oxygen. Certain alkaloid bases were detected in paraffine oils by Weller (*Ber.*, **20**, 2097), and Bandrowski (*Monatshefte für Chem.*, **8**, 224), by agitating Galician oil during several weeks with sulphuric acid, obtained a substance containing nitrogen. This substance solidified at 20°, and it formed a platinum salt containing 19·7 per cent. of platinum. Zaloziecki (*Monatshefte für Chem.*, **13**, 498) neutralized a sulphuric acid extract from the refining of a petroleum distillate with calcic hydrate, and distilled with steam. The oily distillate contained nitrogen, and it formed a platosochloride whose percentage composition corresponded to that of tetrahydrocorridine

$$(C_{10}H_{19}NCl)_2\,PtCl_2,$$

or to the formula

$$(C_{10}H_{21}NCl)_2\,PtCl_2;$$

another insoluble platoso-compound was obtained, to which was assigned either the formula

$$(C_{10}H_{18}NCl)\,PtCl_2, \text{ or } (C_{10}H_{17}NCl)_2\,PtCl_2.$$

Soon after the discovery of the Ohio sulphur petroleum, in a technical examination of crude oil which I was called upon to make, I observed that it contained an unusually large amount of sulphur. An examination of the crude oil was soon undertaken, with particular reference to the sulphur compounds, and there was finally separated an homologous series of sulphides $(C_nH_{2n+1})_2S$, including methyl-, ethyl-, propyl-, butyl-, isobutyl-, pentyl-, ethylpentyl-, hexyl-, with higher distillates containing sulphur compounds not yet identified (Mabery and Smith, *Proc. Amer. Acad.*, **24**, 218; *Amer. Chem. Journ.*, **16**, 83). Large quantities of distillates have been collected after long distillation *in vacuo*, which have proved to be mixtures of sulphur compounds, unsaturated hydrocarbons C_nH_{2n}, and apparently saturated hydrocarbons, either of the series C_nH_{2n+2}, or of the series of hexahydro-aromatic compounds C_nH_{2n}.

The sulphur compounds in Canadian oil have received some attention (preliminary examination, Mabery, *Amer. Chem. Journ.*, **16**, 89). Several members of the series $(C_nH_{2n+1})_2S$ have been recognized since that publication, with evidence of sulphides of another series. The separation of the sulphur compounds from the distillates is extremely tedious, even after a long-continued fractional separation of the sulphur oil. The sole method available, so far as we have proceeded, includes precipitation with alcoholic mercuric chloride and decomposition with hydric sulphide in the presence of alcohol. The product is a mixture, the constituents of which must be separated by prolonged fractional distillation.

The peculiar character of the distillates was observed while studying the sulphur compounds, and, as the Ohio petroleum had never been submitted to chemical examination, and the Canadian oil to only partial study, both products invited further attention. On account of the tendency to decomposition manifested by other constituents of the crude oils than the sulphur compounds, it was evident that these bodies could not be separated by the ordinary process of distillation without such serious decomposition as to render the results of little value. When dis-

tilled in contact with the air all distillates, except the most volatile, were highly colored. Attempts were therefore made to avoid decomposition so far as possible by the exclusion of air, and by conducting the distillations under reduced temperatures. In order, furthermore, to be sure that the distillates should represent as nearly as possible the original constituents, we started with crude oils instead of refinery distillates. In certain portions of our work connected with the separation of constituents that are present in minute quantities, requiring large quantities of material, we have used crude distillates as the starting point; but these distillates were not treated with reagents before we received them.

The distillation of considerable quantities of crude oil *in vacuo* involved certain difficulties which we were long in overcoming. Metallic stills could not be used, and glass was unsafe with large quantities of oil. Only earthenware and porcelain remained, and we have found it difficult to procure earthenware that would support a vacuum. Certain English and German stills of limited capacity have been found serviceable, but the stills which are perfectly satisfactory for such work are those manufactured in the Royal Berlin porcelain factory. One of these stills, with a capacity of fifteen liters, has been in use almost continuously during several months, and it has apparently suffered no deterioration.

In maintaining a vacuum for the continuous distillation of petroleums, especially those containing considerable quantities of sulphur compounds, rubber corks cannot be used in making connections, on account of softening action of the oil on the rubber. It is nearly impossible to select common corks sufficiently free from imperfections; but it was found that common corks could be treated with a rubber lute in such a manner as to make them air-tight. This lute is best made by dissolving pure caoutchouc in very light gasoline, which readily evaporates, leaving a thin, strong film of rubber. When this lute is applied to joints of the apparatus, during the formation of a vacuum, the film of rubber is drawn into the joints and pores of the corks,

thus sealing them permanently, and with an occasional application of the lute there is no difficulty in maintaining any desired vacuum.

In prolonged distillation it is important to regulate the tension, so that it shall be constant during the collection of all distillates. For this purpose a special form of regulator was devised, depending upon the introduction of air away from the still, through a glass stopcock, by means of a long lever. By this means it has been found possible to control the vacuum at any desired point with very little attention. The difference in boiling points in vacuum distillation varies between 60°–65° for the lower constituents, and 100°–125° for portions distilling at 300°–350°. Vacuum distillation prevents serious decomposition even of the highest distillates. We have carried the temperature to 375°, and this is as far as distillation is possible with ordinary connections. The residue above this point is a thick oil, apparently undecomposed; cracking is easily observed, since it immediately destroys the vacuum. For further distillation of this residual oil an apparatus must be devised to avoid the use of any connections other than glass or porcelain.

We have undertaken an examination of Ohio and Canadian petroleum with reference to the various series of hydrocarbons, the nitrogen compounds, the oxygen compounds and the sulphur compounds. This paper gives an account of results obtained in an examination of distillates collected below 150 atmospheric pressure.

[*To be concluded.*]

THE NICARAGUA CANAL.*

BY G. W. SHERWOOD, Civil Engineer.

Mr. Manson's able and comprehensive paper† leaves little to be said with regard to the historical and economic features of the subject, and I desire here to express my unqualified approval of his opinions with regard to *strict* and exclusive governmental construction and ownership of the canal.

The plans for the construction of the canal have been chiefly evolved from the information obtained from surveys made under the direction of Chief Engineer Menocal since 1887, except with regard to the river division from Ochoa to Lake Nicaragua, which I believe are based upon older surveys.

In 1889, the plans were submitted to a Board of Consulting Engineers, which submitted a report, in May of that year. This report was published in *Engineering News* of December 15, 1892, and furnishes an authoritative exposition of the plans and estimates.

Quoting from this report: "The project in detail consists of the following elements:

"(1) Of 10 miles on the east, and 0·57 miles on the west end, of sea level canal dredged in from the coast.

"(2) Of a flight of three locks on each end, all within a distance of about one and one-half miles at one end, and of two miles at the other, by which the ascent is made from the sea level to the summit of level of 110 feet (this elevation being some four feet less on the eastern end, to allow for a necessary fall of three-fourths of an inch per mile in the San Juan River). These locks are shown by the borings submitted to be all founded on rock. The proposed

* Abstract of a paper read before the Technical Society of the Pacific Coast, June 1, 1894, and revised by the author for publication in the *Journal of the Franklin Institute.*

† *Vide*, Transactions Tech. Soc. Pac. Coast, July, 1893.

size for locks, 650 feet by 70 feet by 30 feet deep, seems sufficient for all demands.

"(3) Of a very long summit level of 155·98 miles, consisting of four main parts:

"(*a*) The great divide cuts of three and eight miles in length, respectively, which are shown, by the evidence submitted, to consist chiefly of rock, overlaid with a few feet of earth.

"(*b*) The Deseado, San Francisco, Machado and Tola basins, formed by dams, furnishing 21·57 miles of slack water navigation, 18·13 miles of which require no excavation, and the remaining 3·44 miles earth dredging only.

"(*c*) The River San Juan, raised in level by a dam at Ochoa, so as to furnish slack water navigation, and Lake Nicaragua, furnish together 121 miles of free navigation, of which 36·5 miles require some earth dredging, and 3·83 miles some rock dredging.

"(*d*) An inconsiderable amount (1·63 miles) of canal section in earth, chiefly to connect the San Francisco and Machado basins."

There is evidently an error under the second heading, as the necessary elevation would not be attained by three locks thirty feet deep.

From another source, the information is obtained that Locks 1, 2 and 3 on the east are to have a lift of 30, 31 and 45 feet, respectively; Locks 3 and 4, 42·5 feet each, and Lock 6, a maximum lift of 29 feet at low tide.

In addition, the harbor at Greytown must be reopened; and a harbor constructed at Brito, the western terminus, which is, at present, an open, unprotected roadstead.

The work of construction was begun in 1889, by the Nicaragua Canal Construction Company, under contract with the Maritime Canal Company, and their efforts have been directed chiefly toward reopening the harbor at Greytown. In 1889, the opening from the harbor to the sea had become entirely closed, and the only access to the lagoon was through the mouth of the Rio Colorado, twenty miles below, and an inside channel. A strong current setting westward along the coast, laden with silt from the Rio

Colorado, and assisted by the prevailing winds and heavy surf, is believed to have been the most active agent in closing the entrance. In December, 1889, the construction of a jetty, to the eastward and windward of the old entrance, was begun; and it was gradually extended, until it is now reported to be about 1,000 feet in length. The jetty is 14 feet in width, built of creosoted piles, in bents of twelve piles, eight feet apart, with 14-inch by 14-inch caps, and strongly braced. The spaces between the bents on each side are filled with a row of piles, driven close together. Brush matresses, laden with rock, were sunk in the interior, which soon became filled solid with sand. All the piles and timber for this structure were imported from North Carolina. The creosoted piles have, I believe, been found to resist the action of teredo very well.

With this assistance the channel again broke through, and gradually deepened to about six feet on the bar in June, 1890, since which time it has been used entirely in the commerce of the port.

It was confidently predicted that, with the aid of the dredges which were purchased from the Panama plant, a depth of at least twelve feet would be readily obtained in the channel, but the beneficial effect of the jetty appeared to cease when a depth of between six and eight feet was obtained, and the dredges were found to be unable to work in the heavy surf.

The plans for the future, it is reported, contemplate the construction of a jetty on the other side of the entrance, and the digging out of the channel by dredges suited to the work. The success of this portion of the work does not appear doubtful, but will probably prove very costly, and, perhaps, entail a heavy expenditure for maintenance. The conditions affecting the work are the strong current before mentioned, rapidly filling the angles between the existing jetty and the shore, a very small rise of tide, not more than eighteen inches at most, with a small area of tidal basin, and, during the greater part of the time, a rough sea and heavy surf.

It is unlikely that any difficulty will be found in excavat-

ing the sea-level portions of the canal. This can be done with the dredges alone, as has been proved at Panama, and its cost narrowly approximated. A section about a mile in length and sixteen feet deep has been already completed without difficulty.

The locks on the eastern side have, I believe, been relocated since the report of the Board of Consulting Engineers was made, and I understand that a rock foundation is not obtainable for them. The borings show strata of clay and gravel with boulders, but no rock is found at a practicable depth. The great rise of Lock No. 3, forty-five feet, more than three times as great as any now in existence, would seem to place it in the category of experiments. But, perhaps, the mechanical resources of the age will be equal to the emergency. The locks will be built of concrete.

The great divide cuts contain the bulk of the material to be moved, other than that to be excavated by the dredges, and it is chiefly rock. This is a favorable condition, as steeper slopes will be permissible, and this material will, perhaps, be more easy to move than the heavy clay which is found thereabouts, owing to the enormous and constant rainfall of that region.

The most daring and dangerous feature of the plans for the canal is found in the great basins; and to withdraw from obscurity the facts concerning the difficulties that beset the work of constructing them, is the writer's excuse for venturing upon this well-worn subject.

The Cano Deseado on the east, and the Limpio, a branch of the Cano Chanchos, on the west, head nearly together on opposite sides of the pass that is to be utilized for the Eastern Divide cut. To form the basin of the Deseado, a dam, 1,050 feet long and 70 feet high, must be built across its valley at Lock No. 3. In addition, gaps in the surrounding ridges, aggregating over a mile in length, must be filled with embankments of varying height.

From the other, or western, side of the divide, a low ridge extends to Ochoa, a profile of which may be found in the supplement to *Engineering News* of September 14, 1889. It is Profile "D." By filling the gaps in this ridge, the San

Francisco basin will be formed. This ridge is cut by three considerable streams, the Chanchos, the San Francisco and the Peary, flowing southward into the San Juan; and there are many other gaps in the ridge falling below the elevation of the summit level, so that the dams necessary to fill the depressions in this natural embankment aggregate nearly eight miles.

The Machado Basin, to be made by a dam across the San Juan at Ochoa, occupies the valley of the Cano Machado, which is separated from the valley of the Rio Peary by a narrow ridge. The dam across the San Juan at Ochoa is projected to be "1,250 feet long, with abutments of 650 feet, and 61 feet high."

The valleys of the three streams above mentioned are each about one-fourth of a mile in width, and, where the embankment line crosses, have an elevation of about 50 feet above sea-level. This will necessitate dams at least 60 feet in height. There are several other depressions of equal depth from 300 to 600 feet wide. The remaining gaps will require embankments of varying height. The borings reveal that the alluvial deposit of the valleys is underlaid by clay, but no underlying strata of rock have anywhere been found.

The embankment line crosses the Rio Peary where it issues from a large morass known as the Florida Lagoon. The surveying parties were accustomed to cross the marshy places near the river by bending over the tall grass and walking upon it; and upon the site of the proposed dam at this point, a pole has been pushed down forty-five feet by the mere pressure of the hand.

The plans for the construction of these dams contemplate the building of a double-track railroad along the embankment line, at the level of the top of the embankments, from the divide cut westward to Ochoa, and across the river; and eastward, to the Deseado embankments. The dams are to be built of loose rock brought from the divide cut by this railroad. The dams in the larger depressions, according to published reports, are to have a base of 500 feet and a width of 25 feet or more on top.

The Board of Consulting Engineers has stated in their report, with regard to this feature of the plans, as follows:

"There is the possible hazard, in respect to the San Francisco and other basins, that they may not prove sufficiently retentive, owing either to leakage around the ends, or under the bases of the dams and embankments, or to concealed permeable strata beneath the natural surface. We deem this a remote danger, since both the surface and subterranean formations, so far as revealed by borings and by the reports of the observations of reliable men, familiar with the locality, are favorable.

"For a work of ordinary magnitude, we would accept such evidence as ample; but, in view of the great area and volume of the basins, we agree that the possibility ought to be covered by the estimate. The probability is great that there are no permeable strata beneath the surface; if they exist, they might not necessarily cause leakage; and even if leakage resulted, it would not necessarily do serious harm. Concentrated leakage, if it occurred, *might possibly* be remedied, and if it should develop at all, would be likely to occur at an early stage of the work of construction. The worst result to be feared is, that it might compel a modification of the original features of the project, enforcing a lowering of the water-level at certain points, and at an additional cost of about $7,000,000."

This last statement would have been much clearer if it had explained what modification of the plans is possible, resulting in a lowering of the water-level at certain points, and where those "certain points" are located.

It is difficult, also, to understand why leakage should develop "at an early stage of the work of construction," for it surely cannot be intended to allow the basins to fill until the dams are nearly or quite completed, with only one railroad to carry the material.

This method of dam construction upon such foundations and under the conditions that prevail there, will, no doubt, prove a revelation to the hydraulic engineers connected with this Society. There is, so far as I know, no precedent for such works under such conditions. Yet this

is the vital feature of the plans. The basins would dispose of the objection always urged against this route, the necessity of numerous locks, and also of the tremendous problem of cross drainage east of Ochoa.

Even supposing the dams can be built in this manner, there still remains a problem of at least equal difficulty to be dealt with, the construction of wasteways to provide for the overflow of the San Juan, a river of great volume, and the several smaller streams.

The wasteways cannot be placed in the native rock, or upon a rock foundation, for there is none between Ochoa and the divide cut.

It certainly cannot be considered any slight problem to conduct a river like the San Juan, whose mean flow at the Lake is 14,924 cubic feet per second, according to Mr. Manson's authority, and at flood much greater, down a fall of sixty feet or more, without any rock foundation for the works. I have, however, never seen this matter referred to in any reports or discussions on the canal project; and the Board of Consulting Engineers have not touched upon it.

It must be taken into consideration that the dams and wasteways must be built to last forever. It will never be possible to drain the summit level for repairs, because of its enormous volume, without stopping the canal service for many months; and I do not understand that any provision is to be made for such a purpose. Should a wasteway be undermined, or the smallest embankment give way, a long time must elapse before repairs could be made.

The rock in the divide cut is soft and rotten, and will rapidly disintegrate under the conditions existing there. It is useless for construction purposes.

The writer is of the opinion that the dams and wasteways cannot be built, in the manner contemplated, so as to permanently resist the forces tending toward their destruction; and that if the canal is built, it will be necessary to modify or eliminate these features of the plans.

The difficulties that will attend the work of construction between Ochoa and Greytown are appalling. This whole region is a dense jungle of tangled vegetation, and much of

it is a loathsome morass. There are no roads, or any possibility of maintaining any, on account of the enormous and almost continuous rainfall, which cannot be less than 400 inches per year. Not a stick of timber or a block of stone suitable for construction purposes exists there. Even the ties used for the railroad already built were brought from Louisiana.

The Canal Company purpose attacking the problem by building a "low-grade" railroad from Greytown to Ochoa, following the canal line to the divide and the embankment line from there to Ochoa, but a lower level than the railroad on the top of the embankments, on the southerly side of the ridge, and in the bottom of the valleys, to be used for construction purposes. A section of this railroad, reported to be eleven miles in length, has been built from Greytown across the swamp, and the location made to Ochoa.

The construction of the road across the swamp was a matter of some difficulty. The roadbed was corduroyed with the timber cut from the clearing, and upon this foundation the ties and rails were placed.

The work train, loaded with sand from the canal section near the lagoon, by a steam shovel, was backed in and unloaded by a ballast unloader; and thus a permanent embankment was gradually built up. The construction of the railroad by this method was necessarily very slow. Five months were occupied in the construction of four miles.

With the aid of the low-grade road, the line along the top of the embankments, or the "high-grade" railroad, will be built, which is intended to be maintained permanently.

It will be impossible to make wagon roads, or to use wheeled vehicles of any kind in this region, because of the almost constant rainfall, turning the soil to mud, even if cattle of any kind could live there, which is doubtful. When there is added to this the fact that every stick and stone must be brought in from some outside source, some conception may be formed of the tremendous difficulties to be encountered, and of the enormous expense of work carried on under such conditions.

The climate, except on the beach where the constant

breeze makes the heat more endurable, closely resembles that of the fernery in the conservatory at Golden Gate Park. In the tangled depths of the jungle no breeze is ever felt. Any considerable exertion causes the most profuse perspiration and induces great fatigue. The surveying parties were housed in "shacks," structures consisting of a roof of palm leaves, supported on crotched poles with sides and ends open.

Communication was maintained with headquarters, near Greytown, by steel canoes on the various streams, and the steamer line on the San Juan.

The field work was of the hardest and most disagreeable description. Work never stopped on account of rain. Each instrument man was accompanied by an umbrella-bearer, who protected the instrument as well as possible. The heat was too great to allow of wearing rubber garments, and consequently everyone was continually wet through. This, however, was not especially disagreeable, as it was always warm. Frequently, it was necessary, for days at a time, to wade about in swamps, in mud and water up to the waist, or deeper. The most intense discomfort is caused by mosquitoes, and the only refuge for them is beneath the heavy calico mosquito bar, at night. Innumerable other varieties of insects and reptiles aid the mosquitoes in their work of torment. Nearly all who have been in the jungle for any length of time are afflicted with skin disease similar to ringworm, supposed to be caused by some insect, and for which there has been found no remedy which can be depended upon to cure while the victim remains in the country.

That life, under such conditions, is not conducive to health, is apparent. Nearly all suffer from malarial fevers, though a few escape and others appear to become acclimated. Other frequent disorders are dysentery, boils and a form of gastritis, which causes the victim to vomit for several hours at a stretch, and which leaves him completely prostrated.

There does not seem to be any great difference between the health conditions at headquarters on the beach and in the forest of the San Francisco basin. It was always a

mooted point which was the healthier, or perhaps I should put it, the more unhealthy, locality.

The labor problem is one of the chief difficulties to be solved. The employment of Chinese, who would probably be most efficient on this work, is prohibited by the concession. It is expected that the unskilled labor supply will be drawn from the negro population of Jamaica, and the other West India Islands. The native population make excellent boat crews, and axe-men for the surveying parties, but have an unconquerable aversion to the rougher forms of manual labor, so that little can be expected from them. It will probably be found that, as at Panama, an inferior class of labor must be employed at high wages.

Another obstacle to be met is the possible advent of yellow fever. It would be a miracle if the work should be completed without an outbreak of this dreadful scourge.

On the western division, the conditions, as at Panama, are more favorable. The physical obstacles are less, the climate more healthful, and the rainfall not so large or continuous; and the Tola basin can be eliminated, if necessary.

It would seem that there are here no obstacles that cannot be overcome by an intelligent application of sufficient money.

It will be observed that the Board of Consulting Engineers has raised the estimate of cost from $65,000,000 to $87,800,000.

That it is exceedingly difficult to make a reliable estimate of a work of so extensive a character, even under the most favorable conditions, the Manchester Canal affords evidence. If it is not possible correctly to estimate the cost of a work in a country like England, where the cost of everything necessary is known, the labor supply reliable and efficient, the climate healthful and invigorating, and all the conditions favorable, it is certainly not possible even to approximate the cost of such gigantic work in an unhealthy tropical country, lacking utterly in materials of construction and in efficient labor supply.

Panama furnishes the only precedent for estimates, and the information obtainable from that source is not reliable

or encouraging. From the information obtainable there we can learn only that high wages must be paid for labor which is rendered inefficient by the unhealthy conditions, and the physical impossibility of men doing the same amount of work as in a temperate climate.

That the completion of the canal would be of vast benefit to the commercial interests of the Pacific Coast and the world in general, does not admit of doubt. It is equally certain that a failure, such as the French have made at Panama after the expenditure of an enormous amount of money, would be exceedingly disastrous; and it behooves the American people to insist that the project be proved feasible before they allow their credit in any manner to be pledged to this enterprise.

The bill of the Representative from Washington, to appoint a committee to make inquiry into the matter, is a step in the right direction, provided that the services of a board of competent and disinterested expert engineers are employed.

It is undeniable that the only information we possess concerning the practicability of the route has been collected by the officials of a company who are interested in foisting their scheme upon the Government; and who naturally do not lay any great stress upon the unfavorable features. There is no doubt that the maps in the possession of the company are very accurate, and that the quantities have been calculated with sufficient care. That the conclusions which have been drawn from these data are also correct, is a matter into which careful examination should be made.

Much has been said of the naval advantages that would accrue to the United States from the construction of the canal under Government control, and from the possession of a naval station in Lake Nicaragua. To the thoughtful observer, this must seem doubtful. In the first place, no naval station in Lake Nicaragua, or in any other portion of Nicaragua, has been, or is likely to be, granted to this Government. The control of the canal would involve its protection. The United States is not at present in a position to insure this, and the problem might involve very serious difficulties.

The canal, if built, should be dedicated to the interests of peace, and its neutrality be guaranteed by the great commercial nations of the world. Would it be too great a stretch of the fancy to image the great maritime nations of the world uniting to construct this work so beneficial to all, each contributing a just proportion of the expense, according to the benefits that it would receive?

Let the waterway be made free to the commerce of the world, except for sufficient tolls to provide for its maintenance; and its usefulness be not impaired by any attempt to make it pay interest on its cost.

The brotherhood of nations is not an unattainable dream to this generation. Might not the construction of this great work in such manner be the first step toward a union of the civilized races; and hasten the day when the world shall have forgotten the art of war, and when the nations shall dwell together in peace?

ADDENDUM.

Since this paper was written, the New York *World* has published (May 2, 1894) a letter from a special correspondent sent to Greytown to ascertain the condition of the canal company's affairs.

This letter is very interesting, as it furnishes information relative to the effect of time on the works already constructed; and enables an opinion to be formed as to their probable efficiency.

It is stated in the letter that the channel has filled up so that a vessel drawing only three feet of water was wrecked while trying to enter the bay, and that the *Presidente Carazo*, a small steamer, formerly running between Bluefields and Greytown, and which could get out with six feet of water on the bar, has been imprisoned for six months. It is also stated that the piles in the jetty are "rotten and loose."

The testimony of engineers familiar with the subject would seem to indicate that piles properly creosoted will resist the action of the *teredo navalis* for a long time. If not properly creosoted, their life is very short.

The cause of the filling up of the channel is probably that the angle between the jetty and the shore has become filled up, and that the sand is now flowing around the end of the jetty, and not through a breach in it.

If this is so, it possibly may not matter if some or most of the piles are honeycombed, as the new land formed in the angle would ward off the most destructive forces, and the weighted mattresses with which the structure was filled, assisted by the piles that must be yet unharmed, might still be sufficient to preserve its usefulness. It is probable that the depth of channel before obtained can be regained by merely extending the jetty.

The correspondent has evidently been imposed on by the "American merchant," who told him that it was the plan to turn the water of the San Juan River through between the jetties. This would be an undertaking almost equal to building the canal, besides being useless. The small branch of the San Juan that enters the lagoon has almost no current for many miles from its mouth, and has already filled up a large portion of what was once the harbor of Greytown. It is the intention to cut off this branch at its head; and, as has been stated before, to dredge out a channel between the jetties.

The roadbed of the railroad is said to have sunk beneath the swamp in places, and to be overgrown with weeds. This is what might be expected. The growth of vegetation in this natural hot-house is marvellous, and can only be kept down by constant labor.

The five dredges, for which $600,000 was the reported price, are said to be sunk in eight feet of water. They represent a dead loss, for which the company would no doubt like to be reimbursed by this Government. All the machinery and supplies on the ground are rapidly becoming valueless—are, in fact, rotting.

The length of canal section dredged is stated to be one-half a mile, fifteen feet deep, which has been partially filled up again by natural agencies. This would indicate that some sort of protection for the banks will be necessary, for the sea-level section at least

The account of the manner in which the property of the company has been seized and sold to satisfy its debts, is interesting and instructive. It emphasizes what was hinted at in my paper—that this Government, if it builds the canal, must be prepared to protect its interests there with a strong hand, for it will certainly be necessary while present conditions of government prevail in those countries. The most ardent friend of the canal must regard with uneasiness the construction at such an enormous expenditure of a waterway vulnerable in a thousand places, through a country subject to an unstable government, founded upon the principle that might is right— a country remote from the centers of civilization—unless the work is under the protection of a power that will deal promptly and surely with any infraction of the terms of concession, allowing no quibbling over details.

The statement that the Nicaragua Steam Navigation and Trading Company belongs to the Maritime Canal Company, again "bobs up serenely." The assertion is so often made that this company belongs to one or the other of the canal companies, that a relation of the facts in the case would seem to be in order.

The Nicaragua Steam Navigation and Trading Company possesses a monopoly of the steam navigation of the San Juan River and Lake Nicaragua, and owns a number of steam vessels. The greater part of its stock was purchased by individuals, (who, it is said, were chiefly officials of the canal companies) before the Construction Company began operations; some interest, one-third, I believe, being retained by its former owner. This company leased the tug *Milliard* and lighters belonging to the Construction Company, and did all the lightering and transportation generally for the latter company. It also maintained a supply store at "headquarters," and, by a convenient system of credit, largely absorbed the pay of the negro laborers, to the great disgust of the merchants of Greytown. But it is not known that any of its profits were ever turned into the coffers of either of the canal companies.

LIGHTNING ARRESTERS, AND WHY THEY SOMETIMES FAIL.*

By Alexander Jay Wurts.

The lecturer was introduced by Prof. E. J. Houston, of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

When the first telegraph lines were installed it was noticed that the instruments frequently became damaged during thunder-storms. The wires were charged with static electricity, which, instead of following many turns of wire through the instrument to earth, would puncture the insulation between consecutive convolutions and thus short-circuit the coils. Besides this damage to the instruments, it was noticed that the static charge would sometimes spring from the line, or other metallic parts of the circuit, to neighboring conducting objects, such as nails, iron pipes and the like. It was also noticed that, when discharge occurred in this manner, the instruments were not damaged. In other words, these neighboring objects formed by-paths for the discharge and, in a measure, offered protection to the instruments. As a consequence of such observation, artificial by-paths were constructed, which consisted of two metal electrodes, separated by a small air space. One of these electrodes was connected to the line, the other to earth; and thus the first "lightning arrester" was constructed.

It was then supposed that, when a line was provided with a "lightning arrester," the instruments would be "protected against lightning." The result, however, proved this conclusion to be erroneous. The discharges would sometimes pass to earth over the spark-gap of the lightning arrester, but not infrequently would quite ignore the arrester and, as before, puncture the insulating material of the

* A lecture delivered before the Franklin Institute, March 15, 1895.

instruments. In other words, the discharge was selective. The failure of the lightning arrester was a vexation; but at that time, owing to the small amount of apparatus in use, the damage reckoned in dollars and cents did not call for any special study of the reasons for the selective character of disruptive discharges. In these days, however, the vast amount of capital invested in electrical apparatus of various kinds, and the consequent increased annual loss directly due to these disruptive discharges, have called for a thorough investigation of the subject and the designing of more efficient means of protection.

It is a very significant fact that overhead wires, after being subjected to the influence of thunder-storms, do not show the damage to insulation which one would reasonably expect to find had the wires been actually struck by the lightning discharge. It is not uncommon, however, to hear of wires being "struck by lightning;" in fact, linemen will frequently volunteer to point out the exact spot where the lightning entered the wire. But, so far as I have been able to learn, overhead wires are not struck by lightning. The points usually selected by lightning discharges are trees, lightning-rods, church steeples, tall chimneys, and the like. There seems to be no reason why lightning should strike a horizontal wire, especially when it is insulated from the earth.

Overhead wires may become charged in three ways and combinations of these, viz.: by static induction from the clouds; by dynamic induction from a lightning discharge, and by conduction from the surrounding charged atmosphere. The writer inclines to the theory of conduction.

During thunder-storms, and in many instances during fair weather, the atmosphere becomes charged with electricity at a constantly increasing potential as we recede from the earth. At the top of Washington Monument, Washington, D. C., a potential of 3,000 volts has been measured during thunder-storms, and at the top of the Eiffel Tower a potential of 10,000 volts has been measured. Now, it is well known that lightning is oscillatory. The first oscillation, or discharge, makes a crack or hole through

the atmosphere, and through this the succeeding oscillations take place. About ten to twelve oscillations can be observed, and the time interval is reckoned at about ·00001 of a second. The lightning, therefore, being oscillatory and the atmosphere charged, if an overhead wire be charged by conduction from the atmosphere—that is, become electrically a portion of it—then, with every lightning discharge it would seem as though the potential of the atmosphere would sympathize with the oscillatory character of the lightning, and that the charge in the atmosphere would also oscillate and produce oscillations in overhead wires; and, in fact, in all metallic conductors, such as wire fences, rails, etc. The fact that wires become heavily charged during fair weather offers further evidence that they are charged by conduction from the surrounding charged atmosphere. In some instances, lightning arresters have been known, during perfectly fair weather, to discharge overhead wires at the rate of 140 times a minute.

In any case, whatever the method of charging may be, the discharges from overhead wires seem to be oscillatory, and during thunder-storms they are, in most cases, simultaneous with lightning flashes.

If we raise one end of a trough of water and then quickly lower it, the water will quietly surge back and forth. If, when the water is returning, we again raise the same end of the trough, a wave will be started forward, which, meeting the returning wave, will combine or collide with it, causing a piling up of the water at that point. Further complications may be introduced by repeatedly, and at proper intervals, raising and lowering one end of the trough. If the crests of these waves be carefully examined, it will be noticed that they differ in height and are constantly shifting their positions.

During thunder-storms the static electricity in overhead conductors surges back and forth very much as the water in a trough, and the indications are that electric waves are set up which combine and interfere with each other in such a manner as to produce frequent and unequally distributed points of high and low pressure. The ends of wires are

points of reflection, and at these points the pressure is always great. Whatever may be the true explanation of the apparent idiosyncrasies of disruptive discharges, it is, after all, with facts that we have to deal.

Referring to *Fig. 1*, let *A A* represent the terminals of a static induction machine *L*, a battery of six one-half-gallon Leyden jars, *B*, a spark gap of $\frac{13}{32}''$, and *C*1, *C*2, etc., variable spark gaps, and let the connections be as indicated. With discharges at *B*, discharges will also occur at one or more of the gaps *C*1, *C*2, etc. When *C*1, *C*2, *C*3 are equal, the discharges occur across these gaps indiscriminately. When discharge occurs over small gaps in the neighborhood of *C*1 or *C*2, thread-like discharges are always noticed at *Cn*. And even when *Cn* is increased to $\frac{17}{32}''$ the thread-like discharge is still noticeable with every discharge at *C*1 or

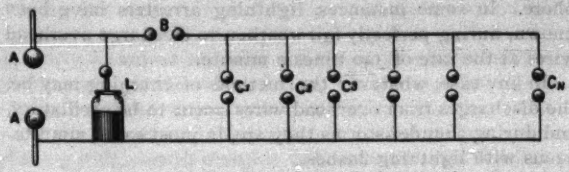


FIG. 1.—Experiment with line arresters, illustrating selective character of discharge.

*C*2. If a large number of spark-gaps, varying among each other as much as 100 per cent., be distributed as *C*1, *C*2, *C*3, etc., discharges will still occur indiscriminately, sometimes across a large gap, sometimes a small one, sometimes across three or four consecutive or widely distributed gaps. When *C*1 is equal to $\frac{6}{32}''$, *C*2 equal to $\frac{17}{32}''$ and placed two, three or more feet away from *C*1, and if *C*3, *C*4, etc., be omitted, then a discharge will occur at *C*2 once in about 500 times without any discharge at *C*1. These experiments demonstrate the selective character of the discharge. If, however, *C*2 be increased to $\frac{18}{32}''$, the discharges will cease altogether at that point, and this last experiment indicates the limit of range over which selection *may* take place under the conditions given. But it is perfectly evident that with a large number of gaps, the probability of discharge across any

one gap is very much less than if only two gaps were present. In other words, if C_1 represents a piece of apparatus which we desire to protect, the protection will be greater as we increase the number of spark-gaps, C_2, C_3, etc., but in no case can there be certainty of protection unless the gap C_1 be relatively so large—or, more broadly speaking, unless the path C_1 offer such a high resistance to the passage of disruptive discharges—as to place it beyond the limit of selection. The apparatus which we have used in the above experiments is different from that employed by nature; the results, however, so far as my observations go, are identical, and the lesson to be learned is simple; it is this: the probability of damage to electrical apparatus connected to overhead wires is lessened as we increase the number of opportunities for discharge from the line.

In summing up thus far, we notice briefly that the line becomes charged, surgings are set up, there are points of reflection which are always points of great electrical strain, there are points along the line of varying intensity or tendency to discharge, these points are constantly shifting their positions, and spark gap lightning arresters are used to conduct disruptive discharges to earth.

The lightning arrester of to day, as a protective device, differs from the lightning arrester of the early telegraph in detail only. A simple spark-gap, one terminal of which is connected to the line and the other to earth, is essentially the lightning arrester now in use. But, with the modern high-potential circuits, it is found that the dynamo current follows the static discharge across the spark-gap of the arrester, causing thereby a short-circuit or dangerous ground on the line. In order to avoid this difficulty, arc-rupturing devices are attached to the lightning arrester, which have for their function the immediate interruption of the dynamo current, without interfering with the further operation of the lightning arrester as a discharging device. "Automatic Lightning Arresters," as they are called, differ among one another in the various means adopted for rupturing the dynamo arc. But the arc-rupturing attachment has nothing whatever to do with the apparatus as a lightning arrester,

so that although automatic lightning arresters vary in outward appearance, and are in general more cumbersome and expensive than the original simple spark-gap arrester, yet, as lightning arresters, they are nothing more than spark-gaps. Various lightning-arrester attachments have been designed for the automatic rupture of dynamo arcs, but owing to the very high potentials which are so often used, they are found to be not only undesirable, but inefficient, the lightning arresters being frequently destroyed by the vicious dynamo arc.

In practice, however, complaints are not so much that lightning arresters are destroyed as that they "fail to protect." It is not unusual to see several different kinds of lightning arresters in a single station, which have evidently been installed with the idea of determining which one of them would prove the most efficient. But such experiments have met with disappointment, for the reason that sometimes one lightning arrester, and sometimes another, would receive the discharge, and the selective character of disruptive discharges was not understood. The failure of lightning arresters is not due to the particular *kind* of lightning arrester, or to the patent under which it is manufactured; it is due largely to the peculiar conditions with which it has to contend, namely, that the discharge is selective, and that, in order to protect apparatus, means must be taken to control these selections, or, at least, to provide so many paths to earth that the probable selection will be one of the many paths provided. In other words, lightning arresters do not "protect," they simply offer opportunities for discharge. These opportunities may or may not be embraced, according to circumstances. But the failure of lightning arresters is not altogether due to the peculiar conditions already referred to. Poor ground connection, inductive resistance in the ground circuit, defective insulation in the apparatus to be protected, and a general misunderstanding of the subject, are not infrequently the cause of serious losses which might otherwise have been avoided.

We have noticed that lightning arresters do not "protect," that they simply offer opportunities for discharge. We

have also noticed that discharges do not pass readily through coils of wire—coils therefore protect. Properly constructed choke coils, connected in the circuit, offer a high resistance to the passage of disruptive discharges, and when used in connection with lightning arresters the combination offers a very reliable means of protecting well-insulated apparatus against lightning. Laboratory experiments, together with tests made under actual working conditions, indicate the advisability of using four choke coils in series, in each wire, with four lightning arresters intervening, as shown in *Fig. 2.* This arrangement is more particularly suitable for the protection of station apparatus. Coils can, however, be used to advantage on the line for the protection of the more expensive translating devices.

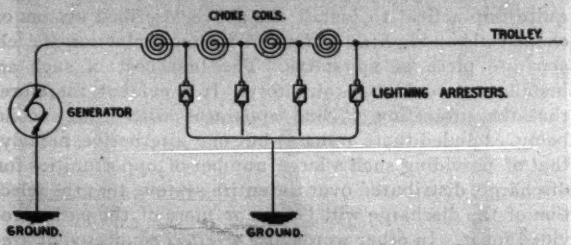


FIG. 2.—Four choke coils with lightning arresters intervening.

The general construction of a choke coil is a matter of considerable importance. A flat spiral possesses some advantages over the helix, but for practical purposes these hardly compensate for the lower cost of the latter, which, for best results, should be wound over a wooden or other non-conducting core. Metal cores and cases should be avoided, because the induced currents in these parts would lower the choking effect of the coils. The number of turns which can be used to advantage is limited. It is found by experiment that, with given conditions, the choking effect increases with the number of turns up to a well defined critical point, after which additional turns fail to have any appreciable effect. It is probable that these critical points vary with the amount of electricity discharged; that is, for heavy

discharges the critical point for maximum choking effect would embrace a larger number of turns than would smaller discharges, and the choking effect for a given number of turns within the critical point would also be greater for heavy than for small discharges. For practical purposes the writer recommends from forty to fifty feet of wire wound either into a flat spiral having an internal diameter of three inches, or into a three-inch helix with a single layer.

Summing up once more, we note that wires become charged, that lightning arresters offer opportunities for discharge, and that coils protect. Bearing in mind these three points, let us note that, with the extensive systems of electric light and power distribution now in use, it would be quite impractical to install the above-described system of choke coils and lightning arresters for the protection of each separate piece of apparatus. The first cost of such an installation would be prohibitory. It is evident, therefore, that the protection of line apparatus with choke coils being excluded there remains but one alternative, namely, that of providing such a large number of opportunities for discharge, distributed over the entire system, that the selection of the discharge will be one or more of the paths provided for it. In other words, *line arresters* connected at frequent intervals offer the only practical method of protecting widely distributed apparatus. But, in order that such an installation may prove satisfactory from a commercial as well as an operative standpoint, the arresters must be cheap, simple, free from moving parts and perfectly reliable without the necessity of regular inspection.

Realizing that these points were not covered by any one of the many automatic lightning arresters which had already been devised, I undertook to simplify the problem, and in my early experiments proposed to equip the lines of electric systems with a multiplicity of spark-gaps, and, at the station, to provide an automatic circuit opening-and-closing device, which, upon the formation of a short circuit across one or more of the spark-gaps on the line, would instantly open and then immediately close. While experimenting with

this system, I discovered that if the electrodes of a lightning arrester were made of zinc, the short-circuiting arc, which had heretofore threatened the life of the lightning arrester, absolutely failed to be maintained. In other words, zinc proved to be what is now commonly known as one of the "non-arcing" metals. Subsequent investigation disclosed the fact that there were four other metals which exhibited similar characteristics, namely, bismuth, antimony, cadmium and mercury.*

The discovery of the non-arcing metals at once solved

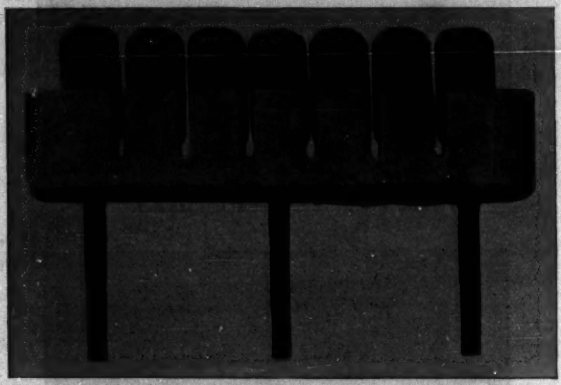


FIG. 3.—Double-pole non-arcing metal line arrester.

the problem of a lightning arrester adapted to the requirements of alternating current circuits, and which would meet the conditions already enumerated.

The non-arcing metal lightning arrester, which is illustrated in *Figs. 3, 4* and *5*, consists, as will be seen, of seven non-arcing metal cylinders, insulated from each other, each one and one-half inches long and three-fourths of an inch in diameter. When installed, the two outer cylinders are

* A full description of the researches and experiments which led to the discovery of the non-arcing metals is given in the *Transactions of the American Institute of Electrical Engineers*, for March 15, 1892.

connected to either leg of an alternating current circuit and the central cylinder to earth, thus forming a double-

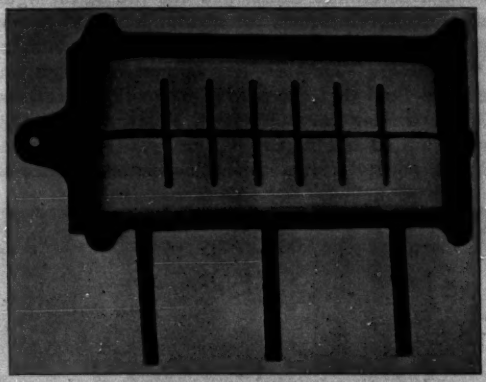


FIG. 4.—Non-arcing metal line arrester.

FIG. 5.—Non-arcing metal line arrester.

pole lightning arrester. In practice, these are manufactured in units for 1,000 volts, so that for 2,000 volts two are con-

nected in series, for 3,000 volts three are connected in series. The diagrams in *Fig. 6* indicate the connections for each potential. There are many thousands of these lightning arresters in actual service, and the experience of three years has fully demonstrated that they are perfectly reliable without the necessity of regular inspection. The simplicity of the device is at once apparent, and the cost to the user is a mere fraction of what was formerly demanded for the best types of automatic lightning arresters. It will thus be seen that, at least for alternating current circuits, the requirements of a commercially serviceable line lightning arrester have been fully met.

The success of the non-arcing metal lightning arrester was such that I was induced to make further investigations

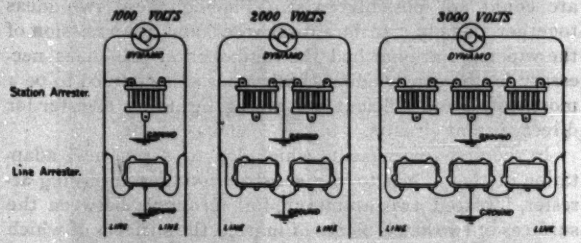


FIG. 6.—Diagrams for lightning arrester connections on circuits of different potentials.

as to the possibility of constructing an equally simple and efficient device for use on direct current circuits. In view of the many experiments which I had made with almost every kind and combination of the ordinary metals, I had become convinced that I should not be able to construct a non-arcing lightning arrester for direct current circuits which would derive its non-arcing property from the nature of the material of the electrodes, as is the case with the non-arcing metal lightning arrester. Accordingly I directed my attention to the possible suppression of the dynamo arc by virtue of the construction or relation of the parts.

I had already observed the remarkable ease with which

disruptive discharges strike over insulating surfaces, as compared to the difficulty with which they ordinarily pierce the air. For example, disruptive discharges will strike over a glass surface, between two electrodes placed eight inches apart, rather than pierce the air between electrodes placed one inch apart and shunting the electrodes in contact with the glass. If ground glass be used and a pencil-mark be drawn between the widely separated electrodes, the ratio between the distances over the glass and through the air is increased. While endeavoring to avail myself of this principle of "surface discharge," as I have called it, it occurred to me that a dynamo arc, in order to exist, must be fed by the vapors of its electrodes, and that if such vapors could be suppressed, or if their formation could be avoided, an arc could not possibly exist. Placing these two ideas together, namely, "surface discharge" and "suppression of the vapors," I at once had the fundamental principles necessary for the construction of what has since proved to be a most simple and efficient non-arcing lightning arrester for direct current circuits.

In the first experiments which led to a practical adaptation of these ideas to the construction of a lightning arrester, I placed two aluminum-foil terminals between the surfaces of two small blocks of marble, the surfaces of which had been carefully ground, and on one of which I had drawn a pencil-mark which should bridge the distance between the foil electrodes. At first these electrodes were placed about two inches apart, the two blocks of marble were firmly bound together with twine, the terminals were connected to the terminals of a 500-volt direct current generator, and disruptive discharges were then caused to pass from one foil terminal to the other, between the marble blocks and over the pencil-mark. It will at once be seen that the function of one of these marble blocks was to furnish a surface discharge plane, that the pencil-mark was to further facilitate the passage of the disruptive discharge, and that the function of the second block, which was firmly bound to the first, was to suppress the formation of vapors, which would otherwise serve to establish a short-circuit under the condi-

tions of the test. No arc being formed, the terminal foils were brought successively nearer to each other, until finally, when the discharge plane had been shortened to one-quarter of an inch, a short circuit was established.

Without entering into the details of subsequent experi-

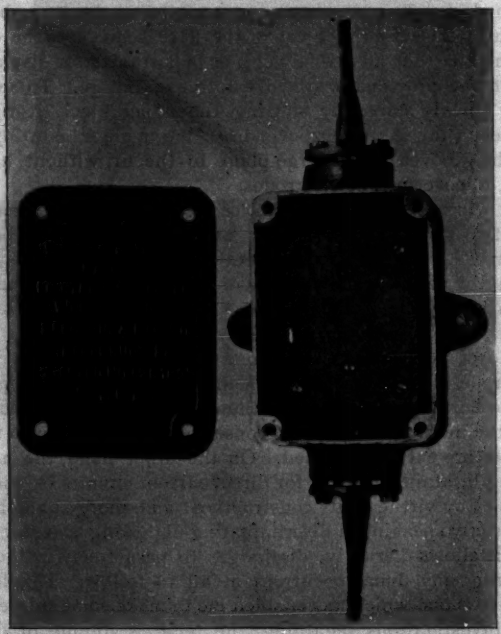


FIG. 7.—Non-arcing railway lightning arrester (for car or line use).

ments leading to the practical construction of a commercial lightning arrester, it may briefly be stated that the final form given to the arrester was that shown in *Fig. 7*. In this form wood, having been found more durable, has been substituted for marble, and, in place of the pencil-marks,

shallow grooves are burned longitudinally between the terminal electrodes, which are placed three-eighths of an inch apart. While submitting this form of lightning arrester to long-continued tests with disruptive discharges, it was found that there was a gradual wearing away of the wood fibre, which eventually ended in the formation of a cavity in which vapors formed in sufficient quantity to establish a dynamo short-circuit. The wearing away of the fibre seemed to be due to the fact that no special vent, or opportunity for displacement, was provided for the disruptive discharge. This evil was quickly cured by slotting the upper block at right angles to the charred grooves in such a manner as to open up the grooves or discharge plane to the air, without, however, uncovering the electrodes.

It will now be proper to notice the distinctive features of the two non-arcing lightning arresters which have been described. The non-arcing metal lightning arrester is non-arcing by virtue of the material of its electrodes, and though "non-arcing," nevertheless allows of the dynamo short-circuit. This is, however, so quickly interrupted, probably by virtue of non-conducting vapors which form between the electrodes during the first rush of current, that no appreciable burning or damage to the electrodes can be noticed, and the melting of fuses and consequent interruption to the service are entirely avoided. On the other hand, the non-arcing lightning arrester for direct current circuits is "non-arcing" by virtue of its construction; and, more than this, is, strictly speaking, a discriminating lightning arrester, in that it allows disruptive discharges to pass freely without allowing any dynamo current at all to follow. This last feature is one which has enabled me to make some interesting investigations regarding the relative volume of discharges from overhead wires during thunder-storms.

While carrying on a series of experiments in Colorado, during the summer of 1893, I connected in series with a number of these discriminating lightning arresters small spark-gaps, into which I inserted pieces of tissue paper, which were intended to act as telltales, and which, by the holes punctured by the discharges, gave me some record of

what was going on. Some of these tell-tale papers are shown in *Fig. 8.* It will thus be seen that, although

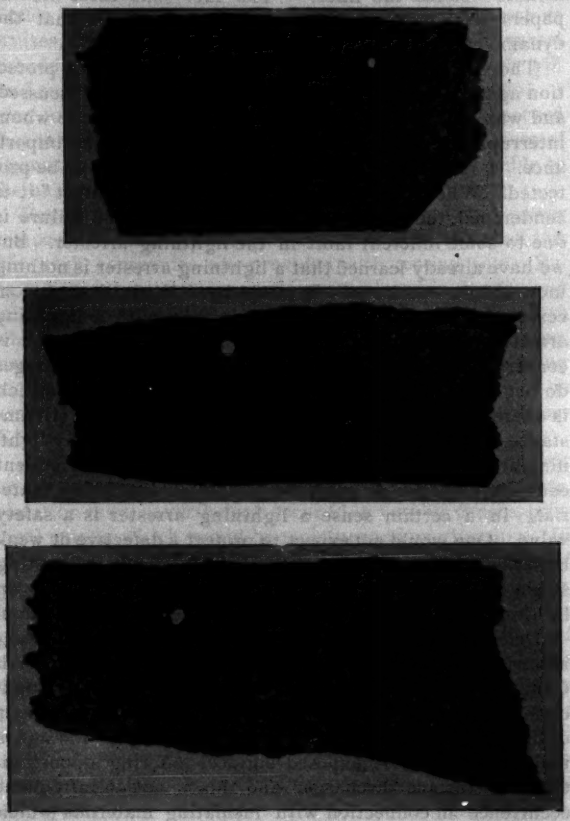


FIG. 8.—Tell-tale papers.

the discharges which caused these holes were larger than is ordinarily obtained with a battery of Leyden jars, they

are not to be compared with the holes which one would expect from the lightning flashes which are so often said to "strike the lines." The fact that these telltale papers were not burned is sufficient evidence that the dynamo current did not follow the discharge.

There is, however, another side to this matter of protection against lightning—one which has been little discussed, and which is almost invariably overlooked by those to whom interruptions due to lightning are a matter of vital importance. I refer to the insulation of the apparatus to be protected. When a lightning arrester "fails to protect" it is condemned, the general opinion being that the failure is due to some inherent fault in the lightning arrester. But we have already learned that a lightning arrester is nothing more than a spark-gap. It would be difficult, then, to conceive of anything fundamentally wrong with a lightning arrester, so far as offering an opportunity for discharge is concerned. We have also learned that disruptive discharges do not always embrace the opportunity for discharge which is offered by a spark-gap lightning arrester. This circumstance, a very frequently occurring one, explains why lightning arresters sometimes fail. Another and all too frequent cause is defective or improperly applied insulating material. In a certain sense a lightning arrester is a safety valve. One would not expect to protect a defective or weak boiler with a safety valve set to blow at or near the bursting strain of the boiler; no more should we expect a spark-gap lightning arrester to protect weak or defective insulation.

Defective insulation results either from weak insulating material, or a faulty *application* of the insulating material. Generally good insulating material is used. Faulty application may result in two ways: (A) Through improper design; (B) Through carelessness or ignorance. Examples under (A) are: (1) exposed surfaces offering opportunities for "surface discharge," and this is not an infrequent occurrence in connection with insulating materials which would otherwise stand very high voltages; and, (2) insufficient allowance for a proper margin of safety. The effects of rough handling, heat and cold, damp and dry atmos-

pheres, dirt and grit (this latter having a particular attraction for electrical apparatus, etc.), demand a margin of safety which is not always appreciated even by the designer. Under (B) might be mentioned a long list of details, such as bruises, cracks, pin holes, cuts, open joints, bits of metal imbedded in the insulation, sharp corners, etc., which will tend to lower the insulation strength fifty, seventy-five or even 100 per cent. And at this point it should be observed that the weakest point in the insulation of a given piece of apparatus (it may be a pin hole or minute crack invisible to the naked eye) is a measure of its insulation strength.

Repair work in shops of local electric light and power companies is liable to be more or less defective, and but few such companies are provided with testing sets. Repaired armatures and converters are placed in service and might stand indefinitely the normal E.M.F. of the circuit to which they are connected, but field discharges, lightning, rise of potential and proximity to other circuits carrying high potentials, demand a margin of safety which cannot be assured unless the insulation be actually tested with an E.M.F. from four to six times the normal.

But, even though the insulation of apparatus be perfect and have its proper margin of safety when installed, deterioration may, nevertheless, occur from various causes, principal among which would be moisture and overheating. In general, it may be stated that if we undertake, by means of spark-gaps, to provide absolute protection against static disruptive discharges, the insulation strength must bear such a relation to the spark-gaps as to place it beyond the limit of selection. Ordinarily, however, absolute conditions do not occur in practice, we can but approximate to them and then philosophically accept a reasonable percentage of failures as inevitable.

The failure of lightning arresters is too often due to careless installation. It may be instructive to note several examples:

(1) One plant is reported as having, for better protection, connected two arresters in series. This was probably done with the idea that if a little was good more would be better.

(2) A large bank of station arresters was grounded to an iron bolt about two feet long, driven into dry sand.

(3) Line arresters were grounded by pushing the ground wires into the earth.

(4) Line arresters were grounded on iron poles, which were themselves set in Portland cement.

(5) An annual inspection of automatic lightning arresters developed the fact that the arresters were nearly all burned out—in other words, that the line was left unprotected.

(6) The ground plate of a bank of arresters was thrown into a neighboring stream, which subsequently changed its course, leaving the ground plate high and dry.

(7) The ground plate of a bank of station arresters was laid on the rock bottom of a neighboring stream.

(8) In a large number of cases a portion of the ground wire is wound into a fancy coil (choke coil). And the list might be indefinitely extended, each such case forming a source of complaint that the arresters "fail to protect." But, when these curious mistakes are located and properly remedied the complaints cease.

Summary.—Overhead wires become charged. They are discharged through lightning arresters, which are spark-gaps. Shifting points of high and low pressure are formed along the line, so that the discharge does not necessarily occur over the shortest or easiest path; that is, the discharge is selective. Lightning arresters offer opportunities for discharge. Coils protect. A liberal distribution of line arresters offers the only practical means of protecting widely distributed apparatus.

Lightning arresters fail to "protect;" first, because of the shifting high- and low-pressure points, or in other words, for lack of a sufficient number of *line* arresters; second, because insulation is defective; and third, because lightning arresters are not properly installed.

SANITARY ENGINEERING.*

By Wm. Paul Gerhard, C.E., Consulting Engineer for Sanitary Works; Mem. Amer. Public Health Association; Amer. Forestry Association; German Samaritan Society; Corresp. Mem. Amer. Inst. of Architects; Honorary Consulting Sanitary Engineer to the Department of Health of the City of Brooklyn, N. Y., etc.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

The subject upon which it is my privilege to address you to-night was, up to within a few years, comparatively unknown. Sanitary engineering—like electrical engineering—is one of the recent branches of civil engineering; sanitary science, the researches of which form one of its foundations, may likewise be considered a new science, although it has, in the last few years, made such rapid strides that its importance is beginning to be more universally recognized.

The general public has but a vague idea of the meaning of the term "sanitary engineering." Many mistaken or narrow views exist in regard thereto, which, I trust, my remarks to-night may help to dispel. Having lived for many years in each of the three continents of Europe, Africa and America, and being, therefore, somewhat of a cosmopolitan, I trust you will overlook the fact that some of the statements which I shall make do not refer exclusively to American conditions.

ARCHITECTURE AND ENGINEERING.

As soon as a science, art or profession expands to such an extent, both in theory and in practice, that its entire field can no longer be mastered by one mind, it divides itself naturally into departments or specialties. We know this has been the case in law, in medicine, in the fine arts, and in the natural sciences. In fact, ours is the age of specialists in all branches of learning, in all arts and

*A lecture delivered before the Franklin Institute of Philadelphia, Pa., February 15, 1895.

sciences. Such a sub-division has also gradually taken place in the profession or art of engineering: thus it came about that sanitary engineering was made a special and distinct branch of the profession of civil engineering.

Let us glance briefly at the origin, and define the meaning, of this new branch.

Centuries ago the whole science and art of building construction were concentrated in one profession. At that time there existed even no division into engineers and architects. Architecture and engineering were not only combined, but merged together with other professions or arts. In those by-gone times a man could be, at the same time, a painter, a sculptor, an engraver, a designer and builder of church edifices, a constructor of fortifications, an engineer of canals. The thought of a Michael Angelo Buonarotti, of a Leonardo da Vinci, of an Albrecht Dürer, will readily recur to you. To-day, however, all this has been changed. The complex requirements of modern civilization, the multiplication of human wants—not to mention the exigencies of business competition—render it well-nigh impossible for such universal genius or master-mind to rise to success. While there may occasionally be exceptional instances of accomplished men who are proficient in many things, as a general rule those will succeed best who limit themselves to the study and practice of one specialty.*

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*After writing down the above, I happened, for the first time, to come across a passage in the poem "Lucile," by Owen Meredith, which expresses exactly the same views. It is as follows:

"The age is gone o'er
When a man may in all things be all. We have more
Painters, poets, musicians and artists, no doubt,
Than the great Cinquecento gave birth to; but out
Of a million of mere dilettanti, when, when
Will a new *Leonardo* arise on our ken?
He is gone with the age that begat him. Our own
Is too vast, and too complex, for one man alone
To embody its purpose, and hold it shut close
In the palm of his hands. There were giants in those
Irreclaimable days, but in these days of ours—
In dividing the work, we distribute the powers."

Lucile, Part I, Canto 1, III.

It is now a little over a century ago that in building construction the first division into the two independent professions of architecture and engineering took place.

Broadly speaking, architecture deals with the ornamental, whereas engineering embraces the purely utilitarian branches of construction. It should be said, however, that while, from a purely business aspect, in the practice of the art, this division exists, the line cannot be quite so strictly drawn as regards the preparation and training required for the subsequent practice of the professions. It lies in the nature of their work that architects must be, to some extent, engineers; they must understand construction in order to be able to design, whereas the reverse of this proposition is not quite so evident, for to find artistic talent and skill in an engineer is rare. To some extent, nevertheless, these two professions have always remained in close touch, and in recent years architects and engineers have once more been drawn together, particularly in such works as pertain to landscape and to domestic engineering.

DEFINITION OF CIVIL ENGINEERING.

The profession of civil engineering has been defined as "the art of directing the great sources of power in nature for the use and convenience of man." The organization of the first State engineer corps occurred in France, in 1791, when the Corps des Ingenieurs des Ponts et des Chaussées was established. As the name implies, the work of these *civil* engineers consisted largely in the development of means for better transportation for passengers, as well as goods, such as the construction of roads, bridges and canals; whereas the *military* engineers constructed works of fortification, and applied engineering construction to military operations. Soon after, followed the construction, equipment and management of railways and the improvement of rivers, harbors and other aids to navigation. Other branches were added from time to time, such as the manufacture and improvement of machinery and mechanical appliances; the operating of mines; the establishment of telegraph and telephone lines; the erection of gas works; the application

of electricity for producing light, heat and power; the fire protection of buildings; the water supply, sewerage and lighting of cities; the drainage, lighting, heating and ventilation of buildings; the reclamation of marshes and agricultural drainage; the laying-out of streets and towns, squares and parks; the construction of piers, docks, sea-dykes, jetties, breakwaters and lighthouses. Broadly speaking, engineers deal both with structures and with machines, the former being, according to Rankine, combinations of materials, the parts of which have no relative motion; and the latter, mechanical appliances whose function is to perform useful work, and the parts of which move.

ENGINEERING SPECIALTIES.

At the present day we may distinguish the following divisions of engineering, viz.:

Military Engineering,	Electrical Engineering,
Railroad Engineering,	Gas Engineering,
Hydraulic Engineering,	Municipal Engineering,
Marine or Naval Engineering,	Sanitary Engineering,
Bridge Engineering,	Landscape Engineering,
Mechanical and Steam Engineering,	Fire Protection Engineering,
Mining Engineering,	Architectural Engineering.

As previously stated, it is impossible for one man to acquire a complete knowledge and practice of all branches, and the tendency to specialization leads engineers to devote themselves to some one particular field. Notwithstanding this division into separate branches, made necessary largely by business considerations, the various branches often meet. Much of the work of the municipal or city engineer, for example, refers to sanitary, to hydraulic, and to gas engineering; the landscape engineer and the architect meet in the laying out of country estates, city gardens and public parks; the sanitary and the mechanical engineer meet in the planning and construction of heating and ventilating plants; the sanitary and the hydraulic engineer, in works of water supply or sewerage for cities, villages and institutions; the architect and the sanitary engineer, in all that pertains to healthfulness of habitations; the architect and the bridge engineer in the iron or steel construction, and

the foundations of large and tall buildings. These examples might be multiplied, but what is said will suffice to explain my meaning.

DEFINITION OF SANITARY ENGINEERING.

If we accept the above definition of civil engineering, then sanitary engineering may be defined as the art and science of applying the forces of nature in the planning and construction of works pertaining to public or individual health; or, to put it in other words, the purpose of all works of sanitary engineering is the promotion of healthful conditions, the avoidance of disease caused by outside influences, which may be brought under control of mankind, and the increase of the duration of life. *It is obvious, therefore, that a general knowledge of civil engineering, of architecture and of sanitary science, in all their branches, should form the basis of the education of the sanitary engineer.*

Some persons among my audience may contemplate taking up the profession of sanitary engineering, or there may be fathers present here to-night who desire to have their sons follow a course of studies which would prepare them for this branch. I will, therefore, even at the risk of wearying you, make an attempt to outline briefly the course of studies and the special training required to enable one to attain the qualifications necessary to practice sanitary engineering. Following this, I shall describe and discuss the principal subjects or problems with which the sanitary engineer deals in his practice. In order to become a competent engineer, the course of study should embrace both theoretical (scientific and technical) education and practical or manual training. The practical education differs according to whether the special branch, which the engineer will follow later on, belongs to mechanical, civil, electrical or sanitary and hydraulic engineering.

COURSE OF STUDY IN SANITARY ENGINEERING.

In order to be able to make use of the forces of nature for the promotion of the comfort, health and welfare of mankind, it is necessary to study and to become conversant

with them; hence, training in the natural sciences and in mathematics forms the basis of sanitary as well as of all other branches of engineering. The study should include mathematics (arithmetic, algebra, geometry, trigonometry and stereometry), astronomy and descriptive geometry; likewise, of the physical sciences, mechanics and dynamics, hydrostatics and hydraulics, aërostatics and aërodynamics; the theory of heat, optics, acoustics, magnetism and electricity. It is also necessary for the engineer to have some knowledge of meteorology, climatology, physical geography, mineralogy and geology; furthermore, of general chemistry, metallurgy, and, in particular, of chemical technology. The study of botany, of the trees of commerce and of forestry is also useful in many ways. In none of these studies, however, must the young engineer student expect to become complete master; even in mathematics, which is to the engineer the basis of all learning, he cannot expect to cover the whole field.

He must become acquainted with the properties of the materials employed in engineering structures, and gain a knowledge of the principles of construction, of the theory of strength of materials, and of the stability of structures. Without this knowledge, he cannot attain eminence in his profession.

All engineers should be good draughtsmen; therefore, the student should practise not only general drawing and sketching, but become skilful in particular in mechanical drawing, in the preparation of engineering drawings, and, to a certain extent, of architectural plans, sections and details. He should also learn geodesy, surveying, levelling, the laying out and staking out of work, and should aim to thoroughly master topographical and map drawing. All these studies are fully as useful to the sanitary engineer in his practice as they are essential to the civil engineer.

The studies mentioned so far comprise the general or preparatory course in engineering. After this should follow special courses in engineering as related to commerce, which comprises the means of transportation and communication on land and on water; in engineering as related to

agriculture; in engineering as related to manufacturing industries and mining; in engineering as related to buildings, and, finally, in engineering as related to public health. He should learn road and street construction, railroad and tramway building, hydraulic engineering, sewerage, water supply, measurement of water power, bridge, roof and tunnel construction, works of drainage and irrigation, canals and locks, river improvements, harbor and sea-coast works, machine construction, and the application of the different classes of motors. A general course in architecture or building construction is also desirable for the well-qualified sanitary engineer, and this should include some knowledge of the trades of carpentry, bricklaying and stone masonry, plastering, blacksmith work, plumbing, gas-fitting and drain-laying.

In addition to these, there should be a course in sanitary science, comprising public and personal health, and a study of the causes and methods of preventing the spread of infectious and contagious diseases. A fundamental knowledge of anatomy and physiology, so useful to men in all conditions of life, is of paramount value to the sanitary engineer, and this should be followed by a special course in "First Aid to the Injured," as now made a feature in all German polytechnic schools. This will prove eminently useful in the subsequent practice of the engineer, in case of accidents or emergencies, whether in the machine shop, on buildings, in railroad disasters, or in sanitary and hydraulic works.

Finally, the general knowledge of language and grammar should not be overlooked, as engineers are frequently called upon to write reports. The study of foreign languages will prove useful in travelling and in many other ways. And, finally, there should be added a general knowledge of law, so necessary when drawing up contracts or preparing specifications, the cultivation of business habits, and the faculty of dealing with foremen and workmen in the superintendence of works.

You will see from all this that the extent of theoretical knowledge and practical acquirements which the sanitary

engineer should possess is quite formidable. It has been truly said that "no man in an ordinary lifetime can properly learn engineering," and that "the learning period of an engineer ends only with his death."

Although it follows clearly from what has been said that the foundation for the special study of sanitary engineering, should be a regular course in civil engineering, it by no means follows that every civil engineer is also a well-qualified sanitary engineer. In order to become competent for the duties of a sanitary engineer, the civil engineer should—in study as well as in practice—give special attention to, and gain knowledge and experience of, all those problems which are correlated to, and which influence, public health. Sanitary engineering covers a very wide field, and is a profession requiring years of preparation and hard work.

ACTUAL PRACTICE OF THE SANITARY ENGINEER.

I will now attempt to give you in outline a very general review of the various classes of work and of the problems arising in the professional practice of the sanitary engineer. I would overstep the limits of this paper were I to discuss any of those questions or topics in detail. I can mention many subjects only casually, and my difficulty is the constant embarrassment of deciding what to omit rather than what to mention.

Speaking generally, much of the work performed by the salaried city or municipal engineers is sanitary engineering. If the sanitary engineer has a private practice, he will often be called upon to act as consulting or advisory engineer for municipal works; or his work will be more in the nature of private architectural engineering and domestic work, such as heating and ventilating of buildings, plumbing and drainage, water supply, sewerage and sewage disposal.

WATER SUPPLY OF CITIES AND OF DWELLINGS.

One problem which belongs to sanitary, and likewise to hydraulic engineering, is the provision of a bountiful supply of pure and wholesome water for cities and towns. A pro-

ject for water works requires investigations as to the quantity needed; as to the quality and available sources of supply; as to the pressure required and the division into pressure districts; as to the means for conducting the water from its source to the places of consumption and the systems of pipe distribution; as to the methods of storing the water, protection against contamination, and, finally, as to the means of purification.

Water is required for many uses, such as for drinking, cooking, washing, bathing and general ablutions; for cleaning; for sprinkling sidewalks and streets, areas and yards and watering gardens; for fire-extinguishing purposes; for flushing water-closets, drains and sewers; for washing carriages and watering horses and cattle; for feeding steam-boilers, supplying fountains, running hydraulic elevators; for industrial establishments, laundries, dyeing establishments, paper factories, breweries and sugar refineries, etc.

From a sanitary point of view, the chief considerations are the sources of supply, quantity, quality, pressure, storage, the material of distributing pipes and the artificial improvement of the water.

The sources for a water supply are rivers and lakes, springs and gathering ponds, which are naturally good, but liable to be polluted by surface washings or by sewage; rain water, which is pure in the country, but contaminated in cities; sub-soil and ground-water, which, away from habitations, is good; shallow wells which are always open to suspicion; and deep artesian or driven wells, which, as a rule, furnish an uncontaminated water supply, but which is not in every instance available for use. A sanitary examination of the source of supply should always be instituted, and comprises a chemical, microscopical and bacteriological analysis of the samples, in the gathering of which particular care is required.

The quantity of water required should be determined according to the rate of growth of population, and according to the special needs of water for domestic and personal, for industrial and for public use. The amount of water required per head per diem will naturally fluctuate with the

customs, desire for cleanliness, and the social conditions of the inhabitants of a place, likewise with the extent of manufacturing industries, the number of public baths, public institutions and public fountains, and, finally, according to the mode of supply, *i. e.*, whether this is unlimited or metered. The consumption also varies at different hours of the day, on different days of the week, and in different seasons of the year, and this should be borne in mind in the design of a water works system.

The quality of the water is another consideration of importance. The fact needs to be emphasized, that clear water is not necessarily wholesome water; and inversely, water may be good without being absolutely pure from the chemist's point of view. Good water, suitable as a beverage, should be transparent, colorless, odorless, tasteless, moderately hard and cold and free from organic impurities and disease germs.

The pressure at which water is supplied is of interest mainly from the point of view of fire protection, but also as regards the supply in dwellings, for a deficient pressure points to the need of storage cisterns in houses, and in some places necessitates the use of domestic pumps to lift the water to the tanks.

Deficiencies in quality, quantity or pressure of the water supply may be the cause of disastrous calamities to life as well as property. To guard against these, stand-pipes or storage reservoirs often form a part of the distribution system. In the reservoirs, the water stored is frequently subject to vegetable growths or algæ, which impart to it a bad taste or odor, or both.

The method of supply is either constant or intermittent; the former is far preferable for sanitary reasons, and may be either a free and unlimited supply, or the supply may be controlled by water meters. The system of supplying consumers by meter measurement prevents unnecessary waste of water, due to leaky house-fittings or carelessness and negligence in use, and is not, from a sanitary point of view, objectionable, as many suppose.

The supply of water to a city may either be brought to

it by open or covered gravity conduits, or it must be pumped, by hydraulic or steam-power, into reservoirs or into pressure conduits. The distribution in the city streets is usually by a network of underground iron pipes, and the domestic water service is effected by smaller distributing pipes, the material of which may have a bad influence on the quality of the supply.

Finally, the artificial improvement of the supply is a problem which concerns the sanitary engineer. It may be accomplished on a large scale, either by sedimentation, by sand filtration on filter-beds, by distillation, by aëration, or by chemical precipitation processes, requiring the addition of substances like alum, lime, or perchloride of iron. In the home, small domestic filters may effect some purification, but nearly all the household filters merely strain the water without actually purifying it, and, unless they are frequently and regularly cleaned and recharged with fresh filtering material, become worse than useless. There are a few household filters which do remove the germs from the water; but all those which have any merit necessarily filter the water very slowly and require occasional cleaning and sterilizing.

Incidental to the use of water as a beverage is the employment of water in its solid form as ice, for the purpose of rendering the temperature of the water more agreeable. It is a popular fallacy that ice is water purified by freezing. Recent progress made in bacteriology has established the fact that germs of disease, such as typhoid germs in drinking water, are not killed by the process of freezing. Danger, therefore, lurks in the indiscriminate use of ice. The business of ice-cutting requires careful watching, and should be under the control of sanitary engineers of Boards of Health. The cutting of ice from ponds or rivers subject to organic contamination, and rendered unfit as a source of ice supply, should be prohibited. Careful householders should, for like reasons, as a matter of precaution, make use of water coolers so arranged that the ice is kept in a separate compartment, so that in melting it cannot mix with the drinking water, or they should order their ice supply only from dealers in artificial ice, manufactured from distilled water.

SEWERAGE.

The water supplied to a city from its water works must be removed after use. To accomplish this is one, though not the only, object of a sewer system. Town sewerage, in the wider meaning of the term, signifies the removal, by underground conduits or sewers, of the sewage of a city, which may include a portion or all of the following liquid wastes: house waste, including excreta and urine; stable wastes, manufacturing wastes from industries using in their processes large volumes of water; waste from water motors and hydraulic lifts; subsoil water; and, finally, surface or storm water, falling on roofs, yards, areas, courts, paved streets and unpaved spaces. From a sanitary point of view, the continuous and instant removal, before putrefaction begins, of all liquid waste products from habitations, must be the chief consideration in order to avoid the pollution of soil and air in and about dwellings, and the contamination of the ground water. To be able to devise a sewerage system, it is necessary to institute many preliminary investigations, which refer to the present and future extent of the drainage area, the configuration or topography of the city, the geology and physical character of the drainage district, the meteorological observations, particularly as to the rainfall of the place, including the frequency and amount of sudden heavy showers; the proportion of rainfall, if any, which is to be admitted into the sewers; the character and quantity of the daily and hourly water supply; the size of population, present as well as prospective, which will derive practical benefit from the sewers, and the comparative density of population in different sections of the city.

Another question of prime importance in the establishment of a sewerage plan, is the final disposal of the sewage; the location of the sewer outfalls; the nature, volume of flow and velocity of current of the water course intended to receive the sewage, the requirements of pumping stations, or the need of sewage purification works. It may be laid down as an axiom that no engineer can give intelligent advice concerning a proposed sewerage system of a city, without having a correct general contour map of the place.

Following these preliminary investigations the sanitary engineer should consider the various sewer systems, the combined and the separate system, the gravity, suction and compressed air systems of sewage removal, and decide which is best adapted to the locality in question. Often it may be advantageous to admit into the sewers only a portion of the liquid wastes enumerated. In many towns storm water may be left out of consideration, as, for instance, where it can be taken care of quite sufficiently by open or covered street gutters, or by a few shallow and short rain-water sewers, discharging in a straight line into the nearest water course. Wherever sewage must be pumped to the outfall, and in all cases where it must be purified before discharge into a water course, the advantages of the separate system predominate.

After deciding upon the system of sewerage best adapted to the needs of a community, a general sewerage plan should be developed, and according to the topography of the city, various lay-outs for the division into sewer districts may be followed, such as the direct or perpendicular system, the intercepting system, the zone or parallel system, the fan system and the radial system, the details of which I cannot describe here. The grade and inclination of the sewers, the resulting velocity of flow, the importance of making sewers self-cleansing, the depth at which they are laid below the street level, the sectional forms and sizes, the material and construction, whether cement or vitrified pipe or iron pipe sewers, concrete, brick or stone-masonry sewers, these are all matters of importance, which the experienced sanitary engineer has to consider. In the construction of the sewers many questions of detail come up, upon which the ultimate success of the system will depend, such as the trenching, the provision of proper foundations in loose soils, the use of invert blocks, the making of water-tight joints in pipe sewers, the proper junction of sewers, the careful alignment and the adjustment of the grade, the smoothness, hardness and durability of sewer pipes and other considerations. Sound, practical judgment will determine the position and number of man-holes and lamp-holes for purposes

of inspection, location and removal of obstructions, the advisability of using devices for flushing sewers, either flushing man-holes, gates or tanks with automatic siphons, and the detail of sewer outfalls. Where rainfall is admitted to the sewers, the construction of catch-basins at street corners and of storm overflows to relieve the sewers in case of sudden heavy showers must be studied. Where sewage cannot be discharged by gravity, pumping stations and sewage pumps must be designed; finally, the house connections must be provided, in wet soils subsoil drains must be laid in the sewer trenches, and in all cases the sewers must be well ventilated.

The problem of sewer ventilation presents many practical difficulties. The prevailing method, by means of perforated man-hole covers, is open to objections, particularly in narrow streets or courts, and the alternative of untrapped catch-basins aggravates the evil, owing to the proximity of the latter to the windows of dwelling houses. Among the various other methods suggested from time to time, I mention ventilation by means of the rain-water pipes of buildings, which is objectionable, first, because during rainstorms, just when sewers require a free vent, owing to the displacement of the air by water, the rain-water conductors cannot act as ventilators; second, because the joints of outside metal leaders are rarely tight; and third, because rain-water leaders often terminate under windows of living rooms or sleeping apartments. Ventilation by lamp-posts or special columns rarely accomplishes much, because they are of too small diameter. The carrying of special sewer vent pipes along the outside of buildings would be somewhat more effectual, but the method is difficult to enforce, expensive, and often troublesome in case of adjoining buildings of various heights. Ventilation of sewers by connection with chimney shafts or boiler flues involves the possibility of explosion, or is objected to by the owners, as it may injuriously affect the chimney draft. Special tall shafts, at the upper ends of sewer lines, are, to some degree, effective, but very expensive. Other propositions include charcoal ventilators in the top of man-holes, which require frequent

removal, material placed in sewers to absorb gases, and the passing of disinfecting vapors or chemical gases into the sewers. Unfortunately, most of these devices suggested are costly or difficult to apply, and the problem is by no means satisfactorily solved. One other method deserves special mention, it being a successful feature of the separate system; this is the omission of the running trap on all house drains, thus making use of the house soil and vent pipes, which are carried up to the roof. With a well-flushed, well-arranged and well-maintained sewer system, under complete control of the municipal engineer, the simple method is perfectly feasible, and gives good results, provided the drainage works of the houses are absolutely air-tight.

A public water supply and a sewer system are improvements which usually go together, and exercise a marked sanitary effect upon the general health of a community. The problem becomes more difficult when there is a water supply without sewerage, in which case the filthy and health-destroying cesspool, or the vault, is the usual receptacle of the sewage pending removal by cartage. Where there is neither sewer nor a water supply, the disposal of filth must be accomplished by dry removal systems, such as the earth or ash closets, or the pail system. Finally, there are certain special systems, such as the pneumatic systems of Liernur and of Berlier, and the mode of pumping sewage by compressed air by the Shone system, of which a practical application could be seen at the recent World's Fair in Chicago, with all of which the sanitary engineer should be quite familiar. Of all systems, that one will be by far the best, from a hygienic point of view, which effects cleanliness by a constant, systematic and quick removal of all manner of liquid organic refuse from houses, streets and towns.

PREVENTION OF POLLUTION OF WATER COURSES.

Rivers and water courses have been utilized as the natural outfalls for the sewage of towns. As the amount of town sewage increases, owing to growth of population, and of its industrial establishments, the streams and water

courses become more and more polluted, to the great detriment of the people living further down stream. River pollution, in numerous instances, has been the result of improved town sanitation by sewerage. Too much reliance has often been placed in the assumed self-purification of rivers. In many instances, furthermore, clear streams flowing through the heart of a city, have been made the receptacle of all its liquid wastes, with the result of turning a once pure water course into an extremely foul open sewer, contaminating the air of the town. This offensive practice cannot be too strongly condemned from a sanitary point of view. The experienced sanitary engineer will uphold the axiom that in cities all natural water courses must be kept unpolluted. Even the smallest open streams should, under no circumstances, be covered or arched over and used as sewers. Filth should be prevented from reaching these open streams, and they should be kept pure with plenty of water and by a free circulation of air, and may, by proper rectification, be used to serve as a natural embellishment of a city.

Regarding larger water courses flowing past a city, the question whether or not sewers may discharge directly into them depends upon a number of factors which must be carefully considered by the engineer. A certain amount of self-purification is, no doubt, always going on, due largely to the sedimentation or subsidence, to oxidation and aëration and to dilution; and with this in view there is a certain degree of permissible pollution. Speaking generally, the larger the volume of the water course, and the greater its velocity of current, the more sewage can be admitted to it without danger of undue pollution. The condition of the water course before it reaches the town should also be considered, but the chief question will always be whether the water of the river is, or may in the future be, used at a point below the sewer outfall as a source of potable water. In that case the direct discharge of unpurified sewage should never be permitted, for the preservation of the purity of water used for public water supply is of paramount importance. We may even go a step further and demand a certain amount of purification of sewage, before discharge into

rivers or lakes, in order to keep these inoffensive even where they are not drawn upon to supply the drinking water, making the required degree of purification variable according to the circumstances of each case. Small lakes, stagnant ponds, coves, bays or inlets should never be used as receptacles for town sewage. In manufacturing districts difficulty often arises from chemical wastes, and from the fact that the volume of water of the stream is considerably reduced on account of the flumes which divert part of the water to use it as motive power. On the other hand, artificial dams, like rapids and natural waterfalls, aid the purification by aëration and oxidation.

SEWAGE DISPOSAL.

The question of the proper disposal of the sewage of populous places is one of the most important, and often difficult, problems which the sanitary or municipal engineer encounters. In many sewered cities of Europe, particularly in the case of inland towns, sewage purification systems have long ago been devised and adopted, while in the United States the difficulty is only beginning to be appreciably felt with the increasing pollution of our rivers. A direct discharge of sewage into a water course or into lakes and tidal rivers is seldom permissible. Even the casting away of crude sewage into the sea can only be countenanced under special conditions, as it quite often leads to a defilement of the beaches, and tends to create mud-bars and silts up the navigable channels at the entrance of harbors. Frequently the argument is used against this method of disposal, that it is a waste of fertilizing materials. It should be said, however, that none of the methods of sewage disposal can be carried out with a view to financial gain. The purification of the sewage is, in all cases, the chief object.

The methods of purifying sewage may be divided into natural and artificial methods. To the former belong the simple sedimentation or subsidence, filtration through soil and broad surface irrigation. Among artificial methods, I mention the simple straining of sewage, mechanical filtration, chemical precipitation, aëration processes, and the

purification by electrical currents. Quite often a combination of two of these methods is adopted, and it is impossible to say, in a general way, which is the method that will yield the best success. The sanitary engineer must study each problem separately and use sound judgment in selecting a method best adapted to the existing conditions. Certain scientific experiments, however, and the actual experience gained in cities having various processes in operation will serve as a useful guide.

Simple sedimentation or subsidence is a slow method which rarely effects more than a mere clarification of the sewage, and removes none of the matters in solution. This is also true of the cruder methods of straining or filtering sewage in mechanical filters, and these processes may be considered rather useful as preliminary methods to be followed by broad irrigation or intermittent downward filtration. Chemical precipitation consists in the addition of certain chemicals, such as lime, or sulphate of alumina, or salts of iron, which act as precipitants, causing the suspended matters and a part of the dissolved impurities to be removed. The precipitation takes place in large sewage tanks, and is effected in a variety of ways. In some the sewage comes to a complete rest for several hours, and this method requires, therefore, a large number of tanks. Or the sewage, after the addition of the chemicals, is made to move slowly through shallow tanks, or it is compelled to follow up and down movements in the same. Finally, instead of large shallow tanks, deep upright tanks, cylinders or wells, placed either above or below the ground, are used in certain chemical precipitation processes. None of the numerous chemical processes effect a complete removal of all foul matters, and where the effluent is required to be very pure, the chemical method is often supplemented by irrigation over, or filtration through, soil. In all precipitation processes a new difficulty arises on account of the unavoidable accumulation of sewage sludge, which contains a large percentage of water. This sludge must be dried, either by spreading it out on well-underdrained land, or by pressing it in filter presses. The sludge cakes have some value as

manure, but a financial return from their sale is seldom realized. In some cities, the solid house and street refuse is mixed with the sludge and burned in garbage-cremating furnaces.

In the natural method of sewage disposal, sewage is made to flow either over or through land prepared for the purpose, and an excellent degree of purification is usually attained. Sewage irrigation over cultivated land is assisted during part of the year by the vegetation, the cultivation of certain crops on the sewage disposal field being perfectly feasible. The difficult feature of the system is the need of large areas of well-drained land. Near cities these are not always available, or when they are to be found they require a large outlay of money. Irrigation and filtration through soil also involve the constant need of manual labor.

Aëration processes are seldom adopted, although the oxidation of the organic matters in sewage, either by forcing air through it, or by causing it to run over a series of terraces or waterfalls, or by dripping it down on wire meshes, appears to be practicable.

The treatment of sewage by electricity was introduced experimentally in England several years ago; more recently it has been tried in the United States on a small scale, but sufficient practical experience is not yet available to permit definite conclusions to be formed as to the results to be attained by the process.

[*To be concluded.*]

NOTES AND COMMENTS.*

THE REGULAR SPEED OF OCEAN LINERS.

The following interesting facts are gleaned from the *Scientific American:*

The records of the Foreign Mail Bureau of the Post Office Department show that, as an ordinary thing, the ocean packets are almost as regular in their departures and arrivals as railroad trains, and, considering the distance they travel, even more so. The science of navigation has been reduced to such accuracy that they may be expected almost upon the hour. Take, for example, the *Campania*, of the Cunard Line. In 1893 she made eight trips,

* From the Secretary's monthly reports.

and her average voyage was 5 days, 20 hours and 18 minutes. In 1894 she made ten trips, and her average was 5 days, 20 hours and 17 minutes; only one minute less in 1894 than in 1893 in a voyage of 2,770 miles in all sorts of wind and weather. Nor is this exceptional. The *Teutonic*, of the White Star Line, made twelve trips in 1893, on an average time of 6 days, 4 hours and 8 minutes. In 1894 she made eleven trips, and her average was just a trifle slower—6 days, 4 hours and 17 minutes. The *Etruria* is a little more irregular. Her average in 1893 was 6 days, 6 hours and 47 minutes. In 1894 it was 6 days, 7 hours and 28 minutes.

The *Havel*, of the North German Lloyd Company, made ten trips in 1893, with an average of 7 days, 7 hours and 38 minutes for a distance of 3 080 miles, from the Needles to Fire Island. In 1894 she made nine trips, with an average of 7 days, 7 hours and 24 minutes. The *Fürst Bismarck*, of the Hamburg Line, made nine trips in 1893. Her average for the year for a voyage of 3,080 miles, was 7 days and 15 minutes. In 1894 she made six trips, and her average was 7 days and 54 minutes. The *Columbia* made nine trips in 1893, with an average time of 6 days, 22 hours and 12 minutes. In 1894 she made six trips, with an average of 6 days, 22 hours and 8 minutes.

The *New York*, of the American Line, though not the fastest, has the best record for regularity of any of the Atlantic fleet. Her average time has not varied for years, and she can be expected almost on the minute every voyage. She has crossed the Atlantic more times and has carried more passengers than any other steamer of her age, and has been more regular about it. The *New York* made fourteen trips, west bound, in 1893, with an average time of 6 days, 21 hours and 31 minutes. In 1894 she made fifteen trips, west bound, with an average of 6 days, 21 hours and 45 minutes. Her sailing distance was 2,770 miles. In 1893 she made thirteen trips, east bound, with an average of 6 days, 20 hours and 30 minutes, which was just one minute faster than her west bound time that year. In 1894 she made fifteen trips, with an average time of 6 days, 20 hours and 24 minutes. Therefore, in crossing the ocean fifty-seven times in both directions, at all seasons of the year, her widest variation for two years was only 1 hour and 21 minutes. The old *City of Chester*, also of the American Line, is another steady boat, her average being 9 days, 15 hours and 11 minutes in 1893 and 9 days, 15 hours and 28 minutes in 1894.

Electrolytic Production of Caustic Soda and Chlorine from Common Salt.—Extensive works, says *Le Génie Civil*, have recently been established at Oldbury, near Birmingham, England, for the electrolytic preparation of chlorine and caustic soda from salt.

The elementary apparatus is a pan about 6 feet in length, 3 in width, and 6 inches in depth, divided into three longitudinal compartments by partitions which do not touch the bottom. To these receptacles there is given a continuous slight horizontal motion in order to cause the circulation of a layer of mercury which covers the bottom. In the lateral compartments there is a

saturated solution of common salt, which is continuously renewed, and into which enter anodes of compressed carbon. A lead cover closes the compartments and communicates, by means of piping, with a collector, which leads the chlorine to the places where it is to be used.

The central compartment is provided with iron cathodes, and in it there circulates a continuous current of water, which carries the caustic soda to a concentration of about 20°.

The electrolytic pans having been connected in series, there is sent into them a current of 550 ampères, at four volts to each pan. Under the action of this current, the chloride of sodium is decomposed. The chlorine, mingled with traces of hydrogen (from three to five per cent., on an average), is sucked up by aspirators, while the sodium dissolves in the mercury, forming a cathode. The amalgam of sodium is decomposed, in turn, in the central compartment; the sodium reacts upon the water and becomes converted into caustic soda, and this action produces a strong electric current which reinforces the general current. Up to the present no effort has been made to collect the hydrogen.

The solution of caustic soda is kept at a density of about twenty per cent., and in this state is sent to evaporators, where it is concentrated into blocks that contain 99·5 per cent. of pure caustic soda.

The establishment contains thirty pans, which permit of the daily production of 1,300 pounds of caustic soda and 1,100 of liquid chlorine.

THE COST OF POWER AT NIAGARA.

The representatives of many established industries, and of not a few new enterprises, throughout the country, are anxiously awaiting the starting into operation of the great electric power transmission plant at Niagara, to learn from the experience of that important enterprise what may be expected to be realized from the utilization of water-powers elsewhere. The success of the Niagara plant will signalize the beginning of a large number of enterprises, more or less ambitious, of the same nature, throughout the country.

The following article, from a recent impression of the *New York Tribune*, contains some information bearing on the subject, which will be read with interest:

The company which has undertaken to develop electricity, at Niagara, on a large scale, for manufacturing and other purposes, has acquired more real estate there than it needs for its own use, in order to furnish sites to such of its customers as wish to establish their business close to the source of their mechanical power supply. But the public has been led to expect that in addition to serving local interests, the company would also furnish electricity to places scores, if not hundreds, of miles away, and there has been much speculation as to the feasibility of carrying such plans into effect. Owing to her proximity to the Falls and her great size and industrial activity, Buffalo has been regarded as the first center of population, removed from Niagara, to be provided for. It is not yet quite clear whether that city feels that it is

enjoying a privilege or conferring a favor in letting the Power Company invade its precincts. Perhaps she has not determined that point herself. The matter is evidently still under consideration. In reply to some inquiries from representative Buffalonians, the Power Company recently offered the following terms: It would let the municipality or a private corporation come to Niagara, take water from the Power Company's canals at the rate of $10 a horse-power, and manufacture its own electricity; or it would furnish power off the turbine shafts at $13, or electricity at the power-house at $18. But if the Power Company undertook to do anything of this sort, it would not contract to deliver less than 10,000 horse-power; hence, Buffalo must agree to take at least that much or none at all. The Niagara people would not accept a franchise to operate a line to and in Buffalo for a shorter time than that for which its own bonds have been issued. No price is given for electricity delivered at a central station in the suburbs of that city, fifteen miles from the Falls, so that the company's own estimate of the probable waste and cost of transmission is still withheld. There would be four kinds of losses: (1) In transforming at the power house up to a high voltage, (2) on the line, (3) in transforming down at Buffalo, and (4) in distribution over street lines to consumers. These could not well amount to less than twenty or thirty per cent. altogether, and they might, perhaps, reach fifty or sixty per cent. But if, for example, they amounted to just one-half, the $18 rate at the generator shaft would mean $36 to the consumer, without adding anything either for interest on the cost of the transmission plant or for operating expenses. This, however, is probably an extravagant estimate. The prices actually given, by the way, are for a twenty-four hour daily supply. Some establishments require power, however, for only ten or eleven hours. Whether it would pay to put in storage batteries to utilize the surplus is a question which their managers must naturally consider. Richard Hammond writes to the *Buffalo Courier* to say that steam-power, on a scale of 1,000 horse-power, for ten hours daily, can be generated in Buffalo, where coal is very cheap, for $21 per horse-power. The Power Company, however, denies this, and estimates the cost at $32, besides quoting various experts as estimating the cost on a twenty-four hour basis at between $45 and $60. In some other cities, where coal is more expensive, it is said to be from $60 to $75. If, after this discussion, Buffalo decided neither to buy on the terms offered, nor to let the Power Company bring in its own lines and supply the market, more distant cities may possibly be deterred by her example from patronizing the Niagara concern; but as the latter supplies its local customers with electricity at $20 per horse-power, in large quantities, there may be a greater industrial development at the Falls than would otherwise result.

PRODUCTION OF SLATY CLEAVAGE IN AMORPHOUS CELLULOSE.

About a year ago the *Journal* printed an account of the interesting discovery by Messrs. Cross, Bevan and Beadle, of certain derivatives of cellulose, which appeared to be adapted to many useful purposes in the arts. The expectations of the discoveries in this respect promise to be fully realized.

In connection with the development of the discovery in its numerous practical applications, Mr. Clayton Beadle made the following singular observation, which he has communicated to the *Chemical News*, viz.:

A cellulose coagulum obtained by the spontaneous decomposition of cellulose thiocarbonate when cut in sections by a knife, can be readily freed from by-products by suspending the sections in water. The sheets so obtained consist of 15 per cent. of cellulose and 85 per cent. of water of hydration. They are of a soft, flexible nature, like rubber. We find that the dehydration can be effected by the application of high pressure, and that a compact, horny sheet can be obtained by this means, containing 10 per cent. of atmospheric moisture. The original coagulum is homogeneous; but, on the application of pressure, under certain conditions, it is found to exhibit slaty cleavage. On tearing, the edge of the film is found to consist of laminæ of uniform thickness. By varying the mode of applying the pressure and other conditions of treatment, it appears the laminæ may be made to vary in thickness. Sometimes the films are found to consist of two laminæ of equal thickness, and sometimes of a number. Films may be obtained which do not appear to exhibit this property. It appears that when the material is dehydrated by the application of pressure, that it does not always tend to compact itself with one film, but often into laminæ, and that their thickness varies with the conditions of the pressure. In order to avoid slaty cleavage in the production of these films, it is necessary to press under conditions that would tend to give rise to laminæ of a thickness greater than that of the ultimate film obtained. Slaty cleavage may be very much increased by passing the dry, thick sheets a large number of times under high pressure between iron rollers.

IRON AND STEEL PRODUCTION IN THE UNITED STATES IN 1894.

The annual report of the American Iron and Steel Association shows that the shipments of iron ore from the Lake Superior mines, in 1894, amounted to 7,748,932 gross tons, against 6,060,492 tons in 1893, an increase of 1,688,440 tons. Our imports of iron ore in 1894 amounted to 167,307 gross tons, against 526,951 tons in 1893, a decrease of 359,644 tons. The imports in 1894 were the smallest since 1878.

The production of pig iron in 1894 was 6,657,388 gross tons, against 7,124,502 tons in 1893, a decrease of 467,114 tons. The production in the first half of 1894 was 2,717,983 tons, and in the last half 3,939,405 tons. Of the total production in 1894 only 222,422 tons were made with charcoal and only 120,075 tons with anthracite alone. Of the total production 3,808,567 tons, or over 57 per cent., were of Bessemer. In 1893 the Bessemer pig iron produced was about 50 per cent. of the total production. The imports of pig iron in 1894 amounted to 15,582 gross tons, which was the smallest annual importation of which we have any record. The largest annual production of pig iron in the United States was in 1890, when it amounted to 9,202,703

gross tons. In 1892 the next largest production was attained, namely, 9,157,000 tons.

The production of Bessemer steel ingots in 1894 was 3,571,313 gross tons, against 3,215,686 tons in 1893, an increase of 355,627 tons. Of the total production in 1894, 1,664,954 tons were produced in the first half of the year, and 1,906,359 tons in the second half. The largest production of Bessemer steel ingots yet attained in this country was in 1892, when 4,168,435 tons were made. The production of open-hearth steel ingots and direct castings in 1894, was 784,936 gross tons, against 737,890 tons in 1893, an increase of 47,046 tons. The production of crucible steel ingots in 1894 was 51,702 gross tons, against 63,613 tons in 1893, a decrease of 11,911 tons.

The production of all kinds of rails in 1894 was 1,021,772 gross tons, against 1,136,458 tons in 1893, a decrease of 114,686 tons. Included in the above total of rails produced in 1894 were 157,457 tons of street and electric rails, against a similar production in 1893 of 133,423 tons, showing an increase in 1894 of 24,034 tons. The production of rails reached its maximum in 1887, when 2,139,640 gross tons were made. The production of iron and steel structural shapes in 1894, not including plate girders, was 505,901 gross tons, against 387,307 tons in 1893 and 453,957 tons in 1892. The production of plate and sheet iron and steel in 1894, excluding nail plate and also excluding skelp iron and steel, amounted to 682,900 gross tons, against 674,345 tons in 1893 and 751,460 tons in 1892.

The production of wire rods in 1894 was 673,402 gross tons, against 537,272 tons in 1893 and 627,829 tons in 1892. The production of wire nails in 1894 was 5,681,801 kegs of 100 pounds, against 5,095,945 kegs in 1893, an increase of 585,856 kegs. The production of cut nails and cut spikes in 1894 was 2,425,060 kegs, against 3,048,933 kegs in 1893, a decrease of 623,873 kegs.

BOOK NOTICES.

Ethics of Literature.—By John A. Kersey, Marion, Ind. Author, 1894.

In many respects this production is a remarkable one, and, on its merits, deserves to be accorded a permanent place in the annals of our contemporaneous literature. The author, evidently, has been not only an omniverous reader, but, also, unlike most of that genus, shows himself to be a thoughtful, original and discriminating critic.

His ethics may, perhaps, best be described as a stout protest against the prevalence of intellectual cant and fraud, which has its origin in the blind and stupid acceptance of authority, as the substitute for the exercise of individual judgment.

The author's grievance, unfortunately, is as ancient as history, and will doubtless continue to the end of time, to give the free thinker in philosophy,

science and religion, his justification for running amuck among the men and things that evoke his inspired fury.

Even the most independent in thought among us will find himself the better for the sort of mental shaking-up and brushing away of cobwebs, to which Mr. Kersey treats us. For it is a lamentable truth that most of us are altogether too willing to accept opinions at second-hand, provided that they bear the trade-mark of respectability. It is much less tiresome to drift with the current than to swim against it.

The onset of this free lance, therefore, has the refreshing interest of novelty, and the reader rises from the perusal of a chapter of the ethics with the feeling of mental stimulation. Now, the reader is conscious of a rude shock to tender sensibilities, as some keen thrust of the author pierces through an armor believed to be of proof; and again he is gratified to find his own half-formed convictions strengthened or confirmed by the author's deft and subtle analysis, or by some incisive criticism or brilliant flash of satire. W.

Practical Telegraphy: A book for self-instruction. By F. E. Wessels, E.S., Philadelphia. Author, 1895. Price, 50 cents.

The object of this pamphlet, as declared on the title page, is to furnish the would-be telegrapher a practical manual for self-instruction. The author, after giving a short sketch of the work of Morse, proceeds to the consideration of the fundamental principles of the electric telegraph, and the mode of action and care of batteries.

Following these come very full instructions in the practice of the art of telegraphy, with illustrations of forms used in commercial and railroad work, tables of abbreviations, etc. The booklet appears well adapted for its intended purpose. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 15, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 15, 1895.

Mr. H. R. HEVL, Vice-President, in the chair.

Present, seventy-three members and seventeen visitors.

Additions to membership since last report, seventeen.

The Secretary reported progress on behalf of the special committee on International Standard for Screw-threads.

The paper of the evening was read by Mr. Arthur Kitson, member of the Institute, on the "Ball Nozzle," a new invention for spraying water, devised

by Mr. Charles V. Pollock, of New York. Mr. Kitson gave an account of the construction of the device and of the various uses to which it has been applied, and offered an explanation of the principle of its operation. The subject evoked considerable discussion. The speaker illustrated his remarks by exhibiting a number of ball nozzles applied to firemen's hose, lawn sprinklers, etc., and showed one of the smaller sizes of nozzles in operation.

On Mr. Colvin's motion, numerously seconded, the meeting passed a vote of thanks to Mr. Kitson for his interesting communication.

On Mr. Chorman's motion, which was also numerously seconded, the subject of Mr. Pollock's invention was referred to the Committee on Science and the Arts for investigation and report.

The Chairman made some remarks apropos to the new building plan, on which the Board of Managers is seriously engaged; giving an account of the steps which have thus far been taken to carry the plan into effect.

The Secretary presented his monthly report, of which an abstract appears in the *Journal*.

Adjourned.

WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR APRIL, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 30, 1895.

GENERAL REVIEW.

The average temperature for April, 1895, 49°·2, is 1°·2 above the average [48°·0] for the past seven years.

The highest recorded temperatures occurred on the 25th and were as follows: Aqueduct, Logania, 90°; Lock Haven, 88°; Carlisle, 87°; Coatesville, 87°; and Pottstown, 87°.

The lowest were on the 4th and 11th: Shingle House, 5°; Saegerstown, 17°; Dyberry, 18°; and Smethport, 18°.

At the close of the month, grain and grass were in good condition, but had made slow growth and all vegetation continued unusually late and backward.

From January 1, 1895, to April 30, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 298°; at Erie, 422°, and at Pittsburgh, 399°.

For the same period the excess in precipitation, in inches, at Philadelphia, was 2·05; and deficiency at Erie 3·96, and at Pittsburgh, 3·09.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
April, 1888	46°·5	2·52
1889	48°·7	4·50
1890	48°·7	3·46
1891	49°·8	2·08
1892	47°·0	2·04
1893	47°·6	4·74
1894	48°·0	3·62
1895	49°·2	3·76

The means of the daily maximum and minimum temperatures, 59°·8 and 38°·7, respectively, give a monthly mean of 49°·2, which is 1°·2 above the corresponding month of 1894.

The average daily range was 21°·1.

Highest monthly mean, 54°·0 at Pittsburgh.

Lowest monthly mean, 42°·7 at Wellsboro.

Highest temperature recorded during the month, 90° on the 25th at Aqueduct, Logania.

Lowest temperature, 5° on the 4th at Shingle House.

Greatest local monthly range, 73° at Shingle House.

Least local monthly range, 52° at Easton and Philadelphia [Weather Bureau].

Greatest daily range, 49° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 3·76 inches, is 0·48 inches more than the average [3·28] for the past seven years.

Only a few stations had snowfall in measurable quantities.

General rains occurred on the 1st, 2d, 8th, 9th, 13th, 22d, 27th, 28th, 29th and 30th.

The largest monthly totals of rainfall and melted snow in inches were: Seisholtzville, 7·09; Hamburg, 6·85; East Mauch Chunk, 6·32; *Philadelphia* [Weather Bureau], 6·14; Forks of Neshaminy, 6·04, and Point Pleasant, 5·99.

The least were: Lock Haven, 0·79; Beaver Dam, 1·29; Saegerstown, 1·40; Elwood Junction, 1·66; Towanda, 1·70, and Davis Island Dam, 1·80.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 10; clear days, 10; fair days, 8; cloudy days, 12.

BAROMETER.

The mean pressure for the month, 30·04, is about ·04 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·67 at Philadelphia on the 12th, and the lowest 29·36 at Philadelphia on the 9th.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Gettysburg, 13th; Le Roy, 25th; Towanda, 25th, 27th, 29th; East Mauch Chunk, 26th; State College, 26th; Grampian, 13th; Uniontown, 13th, 14th; Coopersburg, 1st; White Haven, 27th; Wilkes-Barre, 26th; Easton, 9th; Blooming Grove, 9th; Lewisburg, 27th; Dyberry, 9th, 25th, 27th; Honesdale, 9th, 27th; South Eaton, 9th, 25th, 27th.

Hail.—Gettysburg, 13th; Le Roy, 13th; State College, 13th; Uniontown, 13th; Easton, 2d; Dyberry, 1st.

Snow.—Le Roy, 3d, 15th; Grampian, 2d; Drifton, 2d; Coopersburg, 3d; Smethport, 2d; Blooming Grove, 2d; Dyberry, 2d, 3d; Honesdale, 2d, 3d.

Frost.—Hollidaysburg, 3d, 4th, 11th, 14th, 18th, 19th; Towanda, 18th, 19th, 20th, 24th; Quakertown, 4th, 5th, 18th, 21st, 23d, 24th; Cassandria, 10th, 11th, 14th, 18th, 19th; Emporium, 5th, 11th, 18th, 19th, 20th, 24th; East Mauch Chunk, 5th, 18th, 19th; State College, 18th, 19th, 24th; Saegerstown, 17th, 18th, 19th, 21st, 24th; Uniontown, 3d, 10th, 11th, 19th, 20th, 21st, 24th; Lebanon, 5th, 12th; Williamsport, 18th, 24th; Pottstown, 4th, 5th, 11th, 12th, 18th; South Bethlehem, 3d, 4th, 5th, 11th, 12th, 18th; Easton, 5th, 18th, 19th, 24th; Logania, 18th, 19th; *Philadelphia* [Weather Bureau], 18th; [Centennial Avenue], 11th, 18th, 21st, 24th; Blooming Grove, 18th, 19th, 23d, 24th; Selins Grove, 4th; Somerset, 24th; Wellsboro, 2d, 3d, 4th, 5th, 10th, 11th, 12th, 18th, 19th, 20th, 23d, 24th; Dyberry, 1st, 6th, 11th, 12th, 16th, 17th, 18th, 19th, 20th, 21st, 23d, 24th; South Eaton, 4th, 5th, 6th, 18th, 24th; York, 4th, 19th.

Aurora.—Le Roy, 11th, 19th; Saegerstown, 10th.

Solar Halo.—Le Roy, 12th; *Philadelphia*, Centennial Avenue, 6th, 12th, 17th, 22d; Wellsboro, 12th.

Lunar Halo.—Towanda, 5th; *Philadelphia*, Centennial Avenue, 6th; Wellsboro, 5th.

Parhelias.—Saegerstown, 5th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for April, 1895.

County.	Station.	Elevation above Sea Level (feet).	Temperature.									Precipitation.				Number of Days.			Wind. Prevailing Direction.	Observers
			Maximum.			Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
			Mean.	Highest.	Date.	Lowest.	Date.			Mean.	Greatest.									
Adams,	Gettysburg,		49·8	85	25	28	18	60·6	38·9	21·7	43	3·27	. . .	. . .	10	11	12	7	NE	H. F. Buehler.
Allegheny,	Pittsburgh,	820	54·0	82	25	28	3	63·0	45·0	18·0	33	1·83	0·2	. . .	10	7	11	12	N	O. D. Stewart, W. B
Berks,	Hamburg,	380	49·8	86	25	25	4	59·8	39·8	20·0	42	6·85	. . .	. . .	9	5	14	11	E	William Shipe.
Berks,	Reading,[2]	280	50·0	. .	. .	. .	. .	. .	. .	. .	. .	4·28	. . .	. . .	12	. .	. .	. .	. .	Franklin Yager.
Blair,	Altoona,	1,181	54·5	84	27	30	11	63·3	45·7	17·6	29	2·16	. . .	. . .	9	. .	. .	. .	. .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	49·7	86	25	22	11	62·7	36·7	26·0	47	2·52	. . .	. . .	8	15	3	12	E	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	44·8	76	25	20	11	53·0	35·7	18·2	35	2·65	0·2	. . .	13	8	3	19	SW	G. W. T. Warburton.
Bradford,	Towanda,	754	47·8	80	25	25	11	56·5	37·2	19·3	43	1·70	T	. . .	11	7	8	15	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy,[1]	304	52·1	. .	. .	. .	. .	. .	. .	. .	. .	6·04	. . .	. . .	12	16	. .	14	N	J. C. Hilaman.
Bucks,	Quakertown,	536	47·9	84	25	25	5	58·7	37·1	21·6	40	5·41	T	. . .	13	5	10	15	NE	J. L. Heacock.
Cambria,	Cassandria	2,100	47·8	80	26	24	3	56·1	42·3	13·8	32	3·61	T	. . .	13	11	7	12	SE	A. H. Boyle.
Cambria,	Johnstown,	1,184	52·0	85	26	25	11	64·3	39·7	24·6	43	4·38	. . .	. . .	14	15	9	6	S	E. C. Lowentz.
Cameron,	Emporium,	1,050	49·2	89	26	20	11	60·0	38·2	21·8	48	2·53	T	. . .	8	9	10	11	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	49·6	84	25	23	4	58·8	38·4	20·4	43	6·32	. . .	. . .	10	14	5	11	W	F. C. Winternute.
Centre,	State College—Agricultural Experiment Sta.,	1,191	48·4	80	25	23	11	56·5	40·2	16·3	41	2·23	T	. . .	8	9	4	17	E	Prof. Wm. Frear.
Chester,	West Chester,	455	50·0	84	25	29	4, 11	58·8	41·1	17·7	30	5·37	. . .	. . .	11	14	3	13	NW	J. C. Green, D.D.S.
Chester,	Coatesville,	380	49·8	87	25	25	4, 12	61·2	38·5	22·7	43	4·63	. . .	. . .	11	14	8	8	NE	W. T. Gordon.
Chester	Kennett Square,	275	50·2	85	25	26	4	61·3	39·1	22·2	38	5·74	. . .	. . .	12	10	5	15	S	B. P. Kirk.
Chester,	Phœnixville (29 days),	190	50·3	85	25	30	4	60·1	40·9	19·2	34	5·19	. . .	. . .	10	7	6	17	NW	T. Knowles Pegot.
Chester,	Westtown,‖	350	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .	. . .	. .	. .	. .	. .	. .	John D. Carter.
Clearfield,	Grampian,	1,450	47·2	84	26	20	11	56·5	37·9	18·6	42	3·81	0·5	. . .	11	4	14	13	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	50·8	88	25	28	11	. .	. .	. .	. .	0·79	. . .	. . .	7	13	2	15	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	47·2	80	30	17	11	60·3	34·0	26·3	49	1·40	T	. . .	10	8	10	12	NW	J. G. Apple.
Cumberland,	Carlisle,	480	51·0	87	25	28	18	61·2	40·9	20·3	44	3·75	. . .	. . .	10	14	5	11	SE	J. E. Pague.
Dauphin,	Harrisburg,	480	50·5	84	25	31	11	59·0	42·0	17·0	34	3·67	. . .	. . .	10	10	6	14	E	F. Ridgway, W. B.
Delaware,	Swarthmore—Swarthmore College‡,	361	. .	. .	. .	. .	. .	. .	. .	. .	. .	5·53	. . .	. . .	. .	. .	. .	. .	. .	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	46·6	73	21	19	11	. .	. .	. .	. .	. .	. . .	. . .	. .	. .	. .	. .	W	C. F. Sweet.
Erie,	Erie,	1,400	45·0	76	24	23	1	54·0	36·0	18·0	38	2·09	. . .	. . .	10	9	12	9	NE	P. Wood, W. B.
Fayette,	Uniontown,	1,000	51·4	90	26	27	3	61·2	41·5	19·7	38	4·12	T	. . .	11	9	11	10	NW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	48·9	82	26	26	4	60·9	36·9	24·0	42	2·95	. . .	. . .	9	10	10	10	W	J. C. Boggs.
Huntingdon,	Huntingdon—The Normal College,	650	50·2	86	26	25	4, 11	63·3	37·1	26·2	48	1·97	. . .	. . .	6	1	18	11	W	Prof. W. J. Swigart.
Lancaster,	Lancaster—Franklin and Marshall Col'ge,	413	50·3	83	25	28	11	61·7	38·9	22·8	37	5·07	. . .	. . .	13	10	9	11	E	A. V. Heister.
Lebanon,	Lebanon,	456	51·9	85	25	27	11	63·2	38·6	24·6	42	5·10	. . .	. . .	11	12	5	13	NE	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	530	49·4	83	25	26	5, 12	59·2	39·7	19·5	36	5·40	0·3	. . .	11	13	5	12	NW	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	47·2	80	25	20	2	61·0	33·4	27·6	49	4·24	2·8	. . .	10	10	4	12	N	J. R. Wagner.
Luzerne,	White Haven,		45·2	81	25	21	5	54·5	35·8	18·7	36	4·24	. . .	. . .	11	5	12	13	N	C. M. Driggs.
Luzerne,	Wilkes-Barre,	575	49·9	85	25	26	5, 11	62·7	37·2	25·6	44	2·71	. . .	. . .	7	10	5	15	W	A. W. Betterly.
Lycoming,	Williamsport,		50·0	82	25	29	3, 11	59·0	41·2	17·9	39	2·17	. . .	. . .	10	12	8	10	E	G. D. Snyder, C. E.
McKean,	Smethport,	1,500	46·0	76	25	18	11	57·2	34·8	22·4	48	2·46	1·0	. . .	9	8	12	10	SE	Armstrong & Brownell.
Mercer,	Greenville—Thiel College,	1,000	47·4	80	26	20	11	58·3	36·5	21·8	40	2·35	. . .	. . .	6	20	2	8	. . .	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	51·7	87	25	30	4	61·5	41·9	19·6	40	5·13	. . .	. . .	8	15	7	8	NE	Charles Moore, D.D.S.
Northampton,	South Bethlehem,	339	49·2	84	25	28	5	59·0	39·5	19·5	37	. . .	. . .	. . .	. .	10	6	14	NW	T. Merriman.
Northampton,	Easton—Lafayette College,	325	49·6	81	25	29	4, 11	59·4	39·7	19·7	35	3·91	. . .	. . .	11	13	4	13	. . .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	51·4	90	25	28	4	62·2	40·6	21·6	45	4·23	. . .	. . .	13	11	8	11	SE	Richard Callin.
Philadelphia,	U. S Weather Bureau,	117	51·6	84	25	32	11	60·2	43·1	17·1	31	6·14	. . .	. . .	11	11	3	16	NE	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	52·1	84	25	31	11	61·0	43·2	17·8	30	5·59	. . .	. . .	11	11	5	14	NE	John Comly.
Pike,	Blooming Grove,*[1]		45·8	78	26	24	4	. .	. .	. .	. .	5·21	2·5	. . .	11	2	14	14	W	John Grathwohl.
Potter,	Shingle House,	1,475	45·8	78	26	5	4	59·2	32·5	26·7	45	1·81	. . .	. . .	6	11	3	16	N	H. L. Pearsall.
Snyder,	Selins Grove,	455	49·2	85	23	20	4, 11	63·0	35·3	27·7	48	2·55	. . .	. . .	8	. .	22	8	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	47·8	80	25	20	20	60·8	34·9	25·9	42	2·58	. . .	. . .	5	4	18	8	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	42·7	74	25	20	5	. .	. .	. .	. .	2·21	. . .	. . .	7	8	5	17	S	H. D. Deming.
Union,	Lewisburg	450	49·6	86	25	25	5	61·3	37·9	23·4	43	2·41	. . .	. . .	8	9	5	16	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	44·4	79	26	16	4	54·4	34·3	20·1	43	3·22	1·5	. . .	13	11	4	15	NW	Theodore Day.
Wayne,	Honesdale,	1,000	45·8	77	25	24	4, 11	54·9	36·6	18·3	37	3·39	1·8	. . .	12	9	9	12	E	Andrew Thompson.
Wayne,	(Salem Corners) Hamlinton,†	1,600	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .	. . .	. .	. .	. .	. .	. .	T. B. Orchard, M.D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,490	51·8	85	27	23	3, 4	59·8	43·7	16·1	28	4·46	. . .	. . .	8	. .	. .	. .	. .	Murray Forbes.
Wyoming,	South Eaton,	660	47·4	81	25	25	4, 5	57·7	37·2	20·5	39	3·60	. . .	. . .	9	9	6	15	NW	B. M. Hall.
York,	York,	385	50·0	84	25	28	4, 18	60·8	39·2	21·6	40	3·73	T	. . .	10	14	5	11	W	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [2] Mean temperature 8 + 8 + 2.
† No records. ‡ Records incomplete. ‖ Observed reading. ‡ 19 days.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin																																
Bethlehem,	. .	·43	. .	. .	. .	. .	·03	‡	2·24	. .	. .	. .	·78	. .	. .	. .	. .	. .	. .	. .	. .	·07	. .	. .	. .	. .	·56	. .	‡	·38	. .	4·46
Blooming Grove,	·24	·17	. .	. .	. .	‡	‡	‡	‡	3·10	. .	. .	1·20	. .	. .	. .	. .	. .	. .	. .	. .	·15	. .	. .	. .	. .	·27	. .	. .	·05	. .	5·21
Browers Lock,	. .	·23	·33	. .	. .	. .	. .	1·52	·55	. .	. .	. .	·54	. .	. .	. .	. .	. .	. .	. .	. .	·13	. .	. .	. .	. .	·58	·59	·27	·20	. .	4·34
Coatesville,	·10	·45	. .	. .	. .	. .	. .	1·81	·06	·02	. .	. .	·77	. .	. .	. .	. .	. .	. .	. .	. .	·10	. .	. .	. .	. .	·70	·91	·28	·13	. .	4·63
Coopersburg,	·04	·36	·08	. .	. .	. .	. .	1·86	·84	. .	. .	. .	1·24	. .	. .	. .	. .	. .	. .	. .	. .	·53	·10	·17	·10	. .	·53	·10	·17	·10	. .	5·40
Doylestown,	·06	·42	. .	. .	. .	. .	. .	1·23	·61	. .	. .	. .	·75	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·50	·07	·87	·06	. .	3·03
Dyberry,	·09	·17	·05	. .	. .	·08	·02	·88	1·00	. .	. .	. .	·44	. .	. .	. .	. .	. .	. .	. .	·03	·02	. .	. .	. .	. .	·34	. .	·01	·09	. .	3·22
Easton,	‡	·54	. .	. .	. .	. .	. .	. .	2·28	·01	. .	. .	‡	·42	. .	. .	. .	. .	. .	. .	. .	·01	. .	. .	. .	. .	‡	55	‡	·10	. .	3·91
Forks of Neshaminy,	·07	·33	·11	. .	. .	. .	. .	2·54	·95	·10	. .	. .	·61	. .	. .	. .	. .	. .	. .	. .	. .	·10	. .	. .	. .	. .	·04	·14	·24	·20	. .	6·04
Frederick,	·05	·59	·08	. .	. .	. .	. .	1·84	·65	·02	. .	. .	·72	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·24	18	·20	·22	. .	5·25
Hamburg,	·40	·26	. .	. .	. .	. .	. .	2·60	·28	. .	. .	. .	1·10	. .	. .	. .	. .	. .	. .	. .	. .	·31	. .	. .	. .	. .	1·02	. .	·26	·28	. .	6·85
Honesdale,	·19	·13	·03	. .	. .	·05	. .	·78	1·05	. .	. .	. .	·33	. .	. .	. .	. .	. .	. .	. .	·02	·10	. .	. .	. .	. .	. .	. .	·03	·10	. .	3·39
Kennett Square,	·14	·30	·13	. .	. .	. .	. .	2·05	·44	. .	. .	. .	·80	·02	. .	. .	. .	. .	. .	. .	. .	·08	. .	. .	. .	. .	·56	·55	·37	·30	. .	5·74
Lansdale,	·05	·41	. .	. .	. .	. .	. .	1·85	·78	. .	. .	. .	·65	. .	. .	. .	. .	. .	. .	. .	. .	·07	. .	. .	. .	. .	·75	·08	·24	·06	. .	4·88
Mauch Chunk,	. .	·19	·15	. .	. .	. .	. .	1·44	1·72	·02	. .	. .	1·75	. .	. .	. .	. .	. .	. .	. .	. .	·21	. .	. .	. .	. .	·33	. .	·19	·42	. .	6·32
Ottsville,	·04	·30	. .	. .	. .	. .	. .	1·69	·89	. .	. .	. .	1·15	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	. .	·55	. .	·16	·16	. .	4·99
Philadelphia, a†	·11	·18	·17	. .	. .	. .	. .	2·18	1·11	. .	. .	. .	·49	. .	. .	. .	. .	. .	. .	. .	. .	·07	. .	. .	. .	. .	·04	·36	·52	·31	. .	6·14
Philadelphia, b,	·11	·22	·14	. .	. .	. .	. .	2·22	·78	. .	. .	. .	·51	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .	. .	. .	. .	·53	·21	·48	·26	. .	5·59
Phœnixville,	·06	·63	. .	. .	. .	. .	. .	1·77	·42	. .	. .	. .	·75	. .	. .	. .	. .	. .	. .	. .	. .	·10	. .	. .	. .	. .	·42	·42	·27	·14	. .	5·19
Point Pleasant,	. .	·28	. .	. .	. .	. .	. .	2·88	·66	. .	. .	. .	1·03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·41	·21	·11	·19	. .	5·99
Pottstown,	·35	·33	. .	. .	. .	. .	. .	2·05	. .	. .	. .	. .	·85	. .	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .	1·00	. .	·35	·15	. .	5·13
Quakertown,	·06	·28	·27	. .	. .	. .	. .	1·47	1·00	·05	. .	. .	1·31	·03	. .	. .	. .	. .	. .	. .	. .	·17	. .	. .	. .	. .	·36	·07	·24	·20	. .	5·41
Reading,	·01	·40	·16	. .	. .	. .	. .	1·49	·13	·01	. .	. .	1·00	. .	. .	. .	. .	. .	. .	. .	. .	·01	. .	. .	. .	. .	·90	·05	·15	·07	. .	4·38
(Salem Corners) Hamlinton,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Seisholtzville,	·45	·08	·13	. .	. .	. .	. .	1·11	·07	. .	. .	. .	1·15	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .	. .	. .	. .	·56	·12	·17	·17	. .	7·09
Smith's Corner,	·09	·44	·04	. .	. .	. .	. .	2·00	·73	. .	. .	. .	1·18	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·58	·15	·16	·17	. .	5·60
Swarthmore,	·02	. .	. .	. .	. .	. .	. .	‡	1·00	. .	. .	. .	·55	. .	. .	. .	. .	. .	. .	. .	. .	·01	. .	. .	. .	. .	‡	‡	1·95	. .	. .	3·53
West Chester,	·10	·41	·02	. .	. .	. .	. .	2·19	·21	. .	. .	. .	·88	. .	. .	. .	. .	. .	. .	. .	. .	·11	. .	. .	. .	. .	·58	·26	·34	·27	. .	5·37
Westtown,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
White Haven,	·09	·13	·03	. .	. .	. .	. .	1·83	·36	·05	. .	. .	1·14	. .	. .	. .	. .	. .	. .	. .	. .	·15	. .	. .	. .	. .	·19	. .	·08	·16	. .	4·24
Susquehanna Basin.																																
Altoona,	. .	. .	·05	. .	. .	. .	. .	·24	·26	. .	. .	. .	1·27	·13	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .	·03	·11	. .	·09	. .	2·16
(Aqueduct) Logania,	. .	·30	·01	. .	. .	. .	. .	·83	1·27	·07	. .	. .	·80	·01	·01	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	. .	1·20	·03	·07	·10	. .	4·23
Carlisle,	. .	·02	·22	. .	. .	. .	‡	1·20	·40	. .	. .	. .	·24	*	. .	. .	. .	. .	. .	. .	. .	1·10	·30	·18	·13	. .	3·75
Drifton,	. .	·25	. .	. .	. .	. .	*	1·55	·67	. .	·37	·55	·13	*	. .	. .	. .	. .	. .	. .	*	16	. .	. .	. .	. .	·23	*	·10	·33	. .	4·24
Emporium,	·19	·06	. .	. .	. .	. .	·18	·33	·67	. .	. .	. .	·88	. .	. .	. .	. .	. .	. .	. .	. .	·10	. .	. .	. .	. .	·12	. .	. .	. .	. .	2·53
Gettysburg,	. .	·42	·11	. .	. .	. .	. .	·52	·44	. .	. .	. .	·25	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·80	·25	·15	·27	. .	3·07
Girardville,	. .	·42	. .	. .	. .	. .	. .	1·40	·52	. .	. .	. .	1·11	. .	. .	. .	. .	. .	. .	. .	. .	·16	. .	. .	. .	. .	. .	. .	. .	·78	. .	4·39
Grampian,	·22	·06	. .	. .	. .	. .	·23	·25	1·00	. .	. .	‡	1·65	. .	. .	. .	. .	. .	. .	. .	. .	·10	·04	. .	·08	. .	. .	. .	. .	·24	. .	3·81
Harrisburg, †	. .	·24	·03	. .	. .	. .	. .	·90	·63	. .	. .	. .	·30	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·82	·22	·10	·15	. .	3·67
Hollidaysburg,	. .	·14	. .	. .	. .	. .	·14	·30	·21	. .	. .	. .	1·18	. .	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·34	. .	. .	·15	. .	2·52
Huntingdon,	. .	·14	. .	. .	. .	. .	‡	·45	. .	. .	. .	‡	·93	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·25	. .	. .	. .	. .	1·97
Lancaster,	. .	‡	‡	·64	. .	. .	‡	‡	1·76	. .	. .	‡	·54	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .	. .	. .	. .	‡	‡	‡	2·05	. .	5·07
Lebanon,	·08	·35	·02	. .	. .	. .	. .	1·42	·16	. .	. .	. .	1·02	. .	. .	. .	. .	. .	. .	. .	. .	·14	. .	. .	. .	. .	1·48	10	·13	·26	. .	5·10
Le Roy,	·14	·04	·02	. .	. .	. .	·04	·46	·90	·22	. .	. .	·54	. .	·08	. .	. .	. .	. .	. .	. .	·05	. .	. .	·06	. .	·18	. .	. .	·08	. .	2·65
Lewisburg,	. .	·10	. .	. .	. .	. .	. .	·80	·65	. .	. .	. .	·45	·02	. .	. .	. .	. .	. .	. .	. .	·06	. .	. .	. .	. .	·35	. .	·03	. .	. .	2·41
Lock Haven,	·29	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	·02	·54	. .	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .	·04	. .	. .	·06	. .	0·79
Selins Grove,	·02	·14	·02	. .	. .	. .	. .	·79	·53	. .	. .	. .	·40	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·22	·33	. .	. .	. .	. .	2·55
South Eaton,	·25	. .	·08	. .	. .	. .	. .	·75	1·22	·04	. .	. .	·63	. .	. .	. .	. .	. .	. .	. .	. .	·14	. .	. .	·04	. .	·45	. .	. .	. .	. .	3·60
State College,	. .	·09	. .	. .	. .	·02	·49	·19	. .	. .	. .	. .	·98	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .	. .	. .	. .	·17	. .	. .	·28	. .	1·83
Towanda,	·12	·01	. .	. .	. .	·05	. .	·23	·65	. .	. .	. .	·36	. .	·02	. .	. .	. .	. .	. .	. .	·01	. .	. .	·07	. .	·16	. .	. .	·02	. .	1·70
Wellsboro,	·16	. .	. .	. .	. .	. .	. .	·65	·25	. .	. .	·12	·78	. .	. .	. .	. .	. .	. .	. .	. .	·20	. .	. .	·05	. .	·80	. .	. .	. .	. .	2·21
Wilkes-Barre,	. .	. .	. .	. .	. .	. .	. .	·64	·45	. .	. .	. .	·99	. .	. .	. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	·53	. .	‡	·08	. .	2·71
Williamsport,	·10	·02	. .	. .	. .	. .	. .	·38	·37	·10	. .	. .	·68	. .	. .	. .	. .	. .	. .	. .	. .	·00	. .	. .	. .	‡	·00	. .	. .	·03	. .	0·57
York,	. .	·41	·16	. .	. .	. .	. .	1·12	·25	. .	. .	. .	·30	. .	. .	. .	. .	. .	. .	. .	. .	·07	. .	. .	. .	. .	·75	·30	·25	·12	. .	3·73

†U. S. Weather Bureau Stations. *Missing. ‡Amount included in measurement following.

N DURING APRIL, 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,	·08	·07	·03	.	.	.	.	·20	·08	·22	.	.	·54	·01	·01	.	.	.	.	.	.	·05	.	.	.	.	.	.	.	.	.	1·79
Brookville,	·04	·07	·03	.	.	.	.	·41	1·39	·32	.	.	·92	·04	.	·03	.	.	.	.	.	·06	·08	.	.	.	.	.	.	.	.	3·33
Cassandria,	·05	·08	.	.	.	.	‡	·56	·67	.	.	.	1·73	·11	.	.	.	.	.	.	.	·13	·01	.	.	‡	·24	.	·02	·01	.	3·61
Clarion,	·05	·09	·04	.	.	.	.	·26	·62	·18	.	.	1·81	.	.	.	.	.	.	.	.	·07	·05	.	.	.	·05	.	.	.	.	2·16
Confluence,	·01	·43	·83	·01	.	.	.	·30	·61	·81	.	.	·84	·10	·03	·04	.	.	.	.	.	.	.	.	.	.	·02	·03	.	·06	.	3·37
Davis Island Dam,	·12	·07	·03	.	.	.	.	·20	·30	·21	.	.	·60	·03	·01	.	.	.	.	.	.	·16	·05	.	.	.	.	.	.	.	.	1·60
DuBois,	·09	·30	·15	.	.	.	.	·45	1·70	·28	.	.	·95	·35	.	·05	.	.	.	.	.	·17	·02	.	.	.	.	.	.	.	.	4·41
Elwood Junction,	·02	·08	.	.	·01	.	·09	.	·15	·33	.	.	·85	·07	.	.	.	.	.	.	.	·04	·02	.	.	.	.	.	.	.	.	1·66
Freeport,	·08	·10	·14	.	.	.	.	·25	·72	·15	.	.	·73	·08	·02	.	.	.	.	.	.	·04	·04	.	.	.	.	.	.	.	.	2·13
Greensboro,	·03	·45	·30	.	.	.	.	·40	·45	·46	.	.	·85	·26	·32	·08	.	.	.	.	.	.	·24	.	.	.	.	·05	.	.	.	3·88
Greenville,	·20	.	.	.	.	.	·68	. .	·16	.	.	·88	·30	.	.	.	.	.	.	.	.	.	·13	.	.	.	.	.	.	.	.	2·35
(Immel Reservoir)																																
Lycippus,	·12	·15	.	.	.	.	.	·29	1·20	·58	.	.	1·68	.	.	.	.	.	.	.	.	·32	.	.	.	.	·12	.	.	.	.	4·46
Johnstown,	·08	.	·08	.	.	.	·25	·61	·53	·83	.	.	1·58	.	·12	.	.	.	.	.	.	·15	·01	.	.	.	·12	.	·02	.	.	4·38
Lock No. 4,	·02	·07	·14	.	.	.	.	·22	·89	·23	.	.	1·17	·03	·02	.	.	.	.	.	.	·12	·13	.	.	.	·01	·03	·01	.	.	2·49
Mahoning,	·05	·08	·06	.	.	.	.	·34	·86	·24	.	.	1·58	·11	.	.	.	.	.	.	.	·05	·08	.	.	.	·01	.	.	.	.	3·40
Oil City,	·12	·09	.	.	.	.	.	·12	·72	·29	.	.	1·06	·21	.	·03	.	.	.	.	.	·05	·09	.	.	.	.	.	.	.	.	2·68
Parker's Landing,	·01	·15	.	.	.	.	.	·52	·72	·16	·02	.	1·18	·06	.	.	.	.	.	.	.	·05	·07	.	.	.	·01	.	.	.	.	3·35
Pittsburg,†	·12	·15	.	.	·01	.	·08	·27	·40	.	.	·26	·40	.	.	.	.	.	.	.	.	·22	·08	.	.	.	.	.	.	.	.	1·53
Ridgway,	·11	·06	·15	.	.	.	.	·46	1·63	·12	.	.	·78	·04	.	·02	·01	.	.	.	.	·07	.	.	.	.	.	.	.	.	.	3·35
Saegerstown,	·18	·01	.	.	.	.	·08	·22	·21	.	.	·35	·15	.	·10	.	.	.	.	.	.	.	·34	.	.	.	·06	.	.	.	.	1·40
Saltsburg,	·04	·09	·17	·02	·03	.	.	·40	1·18	·43	.	.	1·19	·36	.	.	.	.	.	.	.	·07	·20	.	.	.	.	.	·04	.	.	4·22
Shingle House,	·35	.	.	.	.	.	·10	·25	·75	.	.	.	·35	.	.	.	.	.	.	.	.	·21	.	.	.	.	.	.	.	.	.	1·81
Smethport,	·30	·10	.	.	.	.	‡	·38	·98	.	.	‡	·50	.	·05	.	.	.	.	.	.	.	·25	.	.	.	.	.	.	.	.	.	2·46
Somerset,	.	.	.	.	.	.	·25	·15	1·25	·78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	·15	.	.	.	.	2·58
Stoystown,	.	·8	·32	.	.	.	.	·35	·75	·18	.	.	·77	·18	.	·03	.	.	.	.	.	.	·09	.	.	.	.	·16	.	·03	.	.	3·04
Uniontown,	·38	·28	.	.	.	.	·20	·36	·87	.	.	·17	1·14	·32	·05	.	.	.	.	.	.	·28	.	.	.	.	.	.	.	.	.	4·12
Warren,	·05	·31	·01	.	.	.	.	·03	1·17	·50	.	.	·56	.	.	·15	.	.	.	.	.	·27	.	.	.	.	.	.	.	.	.	3·05
West Newton,	.	·10	·13	.	.	.	.	·30	·47	·52	.	.	1·50	·10	·13	.	.	.	.	.	.	.	·25	.	.	.	.	.	.	·04	.	.	3·34
Potomac Basin.																																
Chambersburg,	·30	.	.	.	.	.	·01	·85	·25	.	.	.	·25	.	.	.	.	.	.	.	.	.	.	.	.	.	·70	·20	·15	·24	.	2·95
Lake Basin.																																
Erie,†	·24	.	.	.	.	.	·02	·02	·04	1·06	.	.	·22	·03	.	·04	.	.	.	.	.	·40	·01	.	.	.	.	.	.	.	.	2·09

total.
1·46
2·21
2·94
2·63
2·40
2·03
2·22
2·04
2·91
2·04
2·15
2·85
2·39
2·74
2·88
2·32
2·99
2·14
2·59
2·19
2·09
2·13
2·41
2·28
. .
2·09
2·60
2·53
2·37
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2·24
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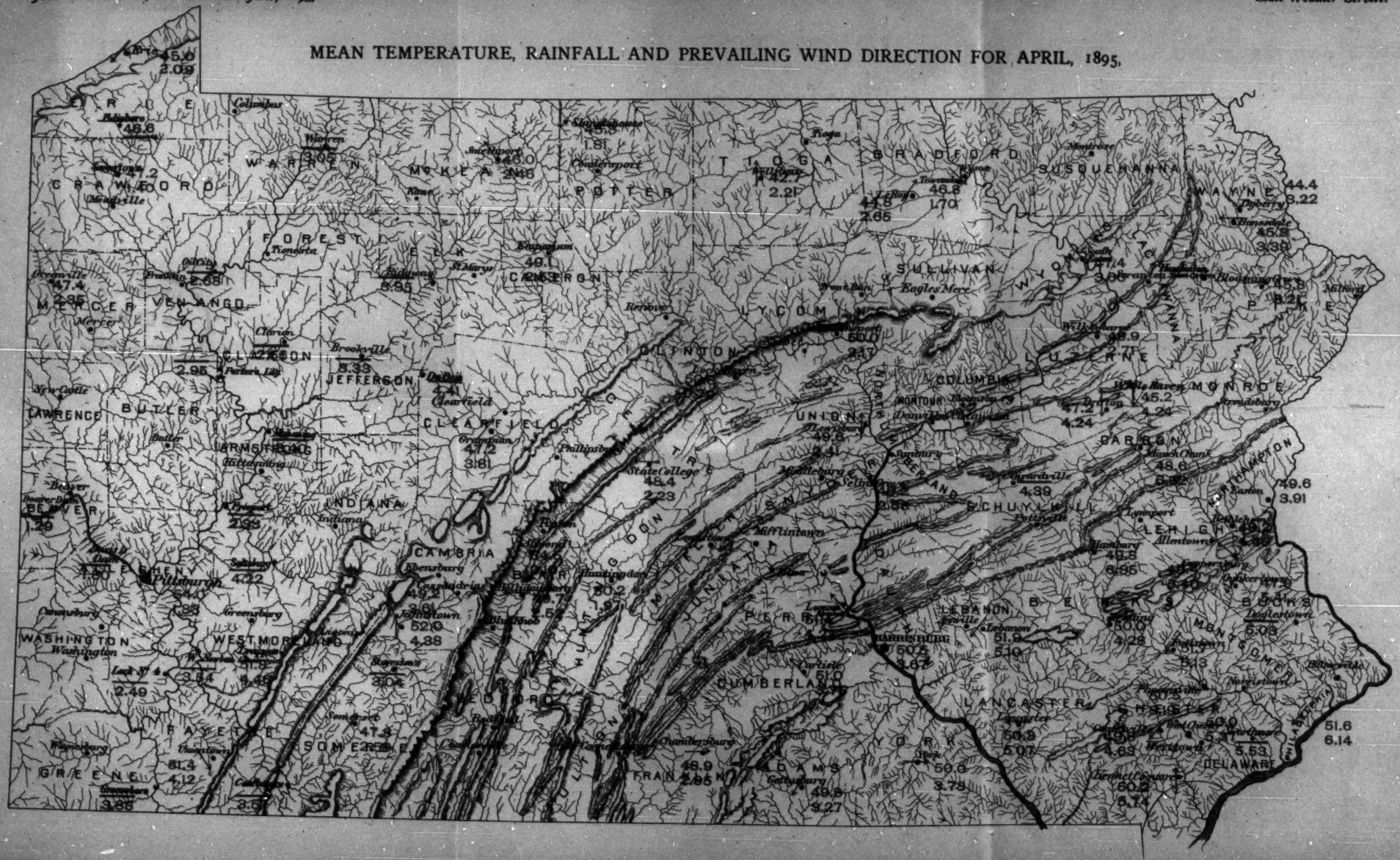
2·16
4·23
3·75
4·24
2·53
3·27
4·39
3·81
3·67
2·52
1·97
5·07
5·10
2·65
2·41
0·79
2·55
3·60
2·83
1·70
2·21
2·71
2·27
3·73

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR APRIL, 1895.